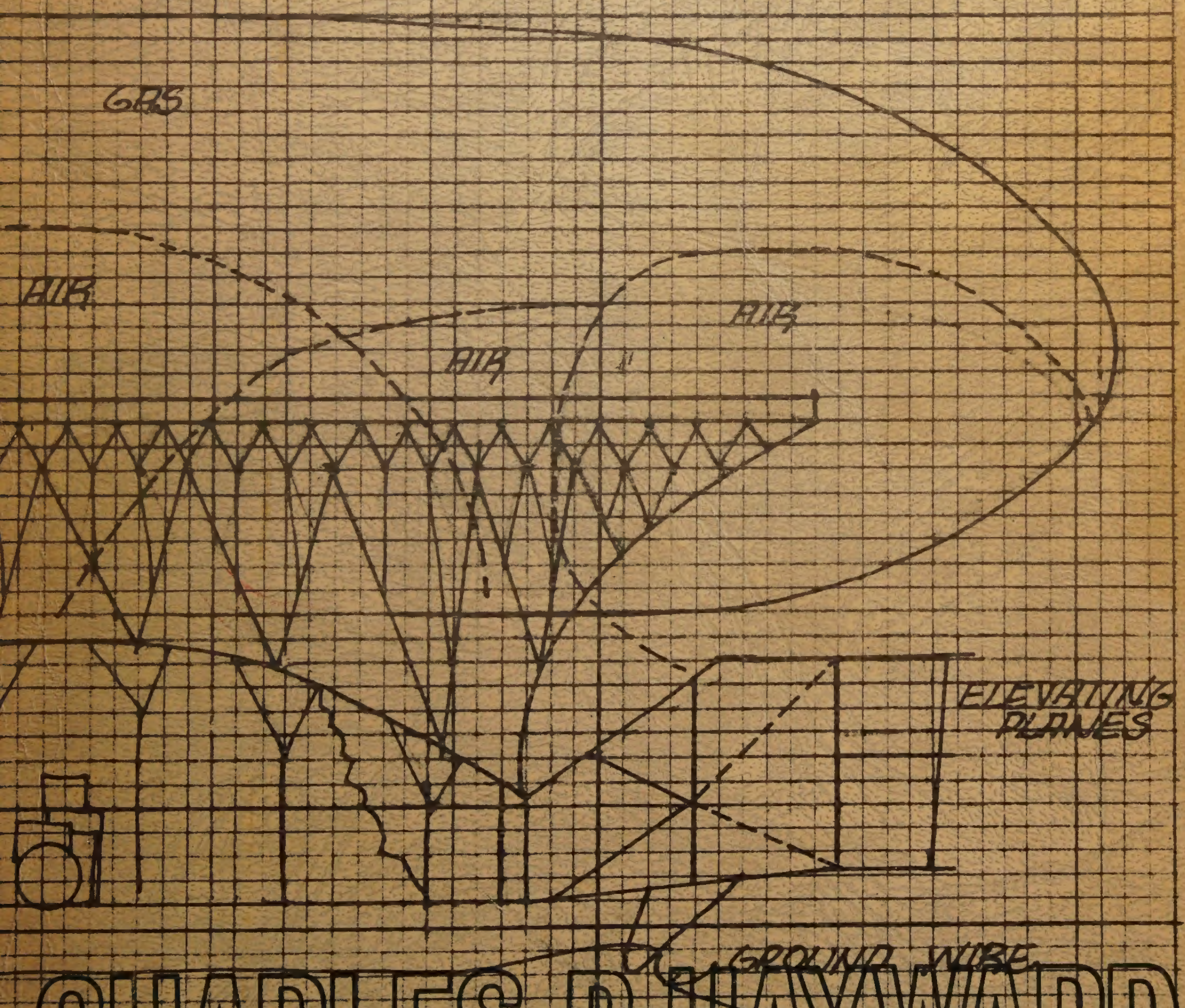
DIRIGIBLE BALLOONS



CHARLES B HAYWARD

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DIRIGIBLE BALLOONS

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INSTRUCTION PAPER

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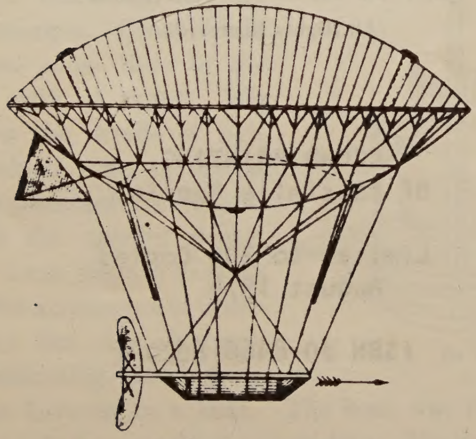

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DIRIGIBLE BALLOONS

INTRODUCTION

Of the first attempts of men to emulate the flight of birds, we have no knowledge, but one of the earliest, perhaps, is embodied in the myth of Icarus and Daedalus. Xerxes, it is said, possessed a throne which was drawn through the air by eagles. The Chinese have sometimes been given credit for the invention of the balloon, as they have for many other scientific discoveries. It is related that a balloon was sent up at Pekin in celebration of the ascension of the throne by an emperor in the beginning of the fourteenth century.

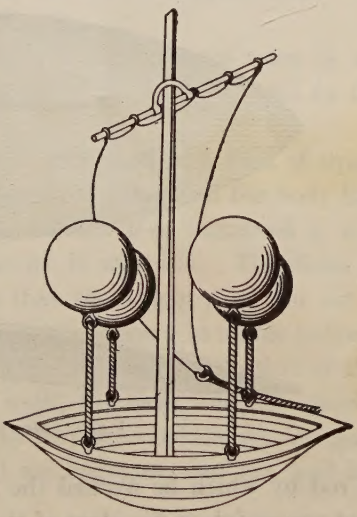

Fig. 1. De Lana Airboat

Early Attempts. Leonardo da Vinci devoted some time to the problem of artificial flight. His sketches show the details of bat-like wings which were to spread out on the downward stroke and fold up with the upward stroke. Francisco de Lana planned to make a flying ship the appearance of which was somewhat like that shown in Fig. 1, by exhausting the air from metal spheres fastened to a boat. The boat was to be equipped with oars and sails for propulsion and guiding. The method in which he purposed to create the vacuum in the spheres consisted of filling them with water, thus driving out the air, then letting the water run out. He thought that if he closed the tap at the proper time, there would be neither air nor water in the spheres. His flying ship was never constructed, for he piously decided that God would never permit such a change in the affairs of men.

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The First Flying Machine. In 1781, Meerwein of Baden, Germany, constructed a flying machine, and was the first, perhaps, to intelligently take into account the resistance of the air. He took the wild duck as a basis of calculation, and found that a man and machine weighing together 200 pounds would require a wing surface of from 125 to 130 square feet. It is of interest to note that Lilienthal, who met his death in trying to apply these principles, over one hundred years later found these figures to be correct. Two views of Meerwein's apparatus are shown in Fig. 2. The construction involved two wood frames covered with cloth. The machine weighed 56 pounds and had a surface area of 111 square feet. The operator was fastened in the middle of the under side of the wings, and over a rod by which he worked the wings. His attempts at flight were not successful, as his ideas of the power of a man were in error.

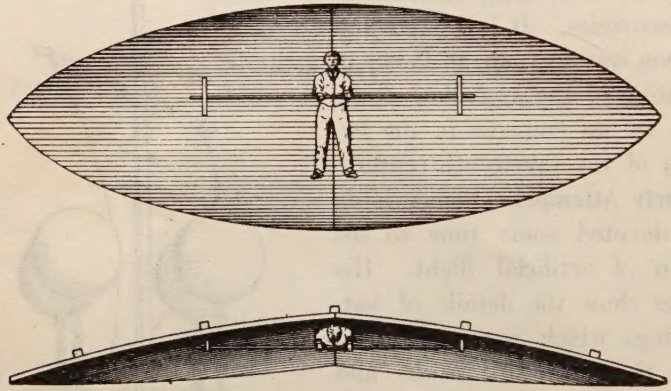

Fig. 2. Meerwein Flying Machine

Classification. All attempts at human flight have gone to show that there are four possible ways in which man may hope to navigate the air. He may imitate the flight of birds with a machine with moving or flapping wings; he may use vertical screws or helices to pull himself up; he may use an aeroplane and sail the air like an eagle; or, lastly, he may raise himself by means of a gas bag and either drift with the wind or move forward by means of propellers.

In these attempts, apparatus of several different types has been developed. The types are classed in two general divisions based on their weight relative to that of the atmosphere, viz, the *lighter-*

than-air machines and the *heavier-than-air machines.* Lighter-than-air machines are those which employ a bag filled with a gas whose specific gravity is sufficiently less than that of the air to lift the bag and the necessary attachments from the earth, and include simple balloons and dirigibles. Heavier-than-air machines, which will neither rise nor remain in the air without motive power, include all forms of aeroplanes.

SIMPLE BALLOONS

Theory. The balloon-like airship has been more highly developed than any other type of aerial craft, probably because it offers the most obvious means of overcoming the force of gravitation. It depends on the law of Archimedes:

"*Every body which is immersed in a fluid is acted upon by an upward force, exactly equal to the weight of the fluid displaced by the immersed body.*"

That is, a body will be at rest if immersed in a fluid of equal specific gravity or equal weight, volume for volume; if the body has less specific gravity than the fluid in which it is immersed it will rise; if it has a greater specific gravity it will sink. Therefore, if the total weight of a balloon is less than the weight of all the air it displaces it will rise in the air. It is, then, necessary to fill the balloon with some gas whose specific gravity is enough less than that of the air to make the weight of the gas itself, the bags, and the attachments, less than the weight of the air displaced by the whole apparatus. The gases usually employed are *hydrogen, coal gas*, and *hot air.*

At atmospheric pressure and freezing temperature, the weight of a cubic foot of air is about .08 pound; the weight of a cubic foot of hydrogen is about .005 pound, under the same conditions. According to the law of Archimedes, a cubic foot of hydrogen would be acted upon by a force equal to the difference, or approximately .075 pound, tending to move it upwards. In the same way, a cubic foot of coal gas, which weighs .04 pound, would be acted upon by an upward force of .04 pound.

It is evident, then, that a considerable volume of gas is required to lift a balloon with its envelope, net, car, and other attachments.

Further, it requires almost twice as much coal gas as hydrogen, under the same conditions, for we have seen that the upward force on it is only half as great. The lifting power of hot air is less than one-eighth as great as that of hydrogen at the highest temperature that can possibly be used in a balloon.

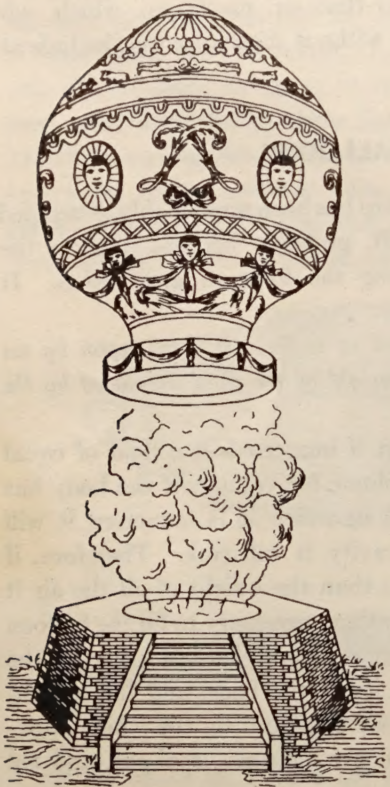

Fig. 3. Montgolfier Balloon

The general type of lighter-than-air machines may be divided into *aerostats* (ordinary balloons, which are entirely dependent on wind currents for lateral movement, and which are often the chief features at country fairs) and dirigible balloons or *aeronats* (air swimmers). Dirigible balloons employ the gas bag for maintaining buoyancy, and have rudders to guide them and propellers to drive them forward through the air in much the same way that ships are driven through the water.

The First Balloon. For several years, Joseph and Steven Montgolfier had been experimenting with a view to constructing a balloon: in the first place by filling bags with *steam;* then by filling bags with *smoke,* and finally by filling bags with *hydrogen.* These attempts were all failures, for the steam rapidly condensed and the smoke and hydrogen leaked through the pores in the bags. They finally hit upon the idea of filling the bag with *hot air,* by means of a fire under its open mouth. Several balloons were burned up, but the next was always made larger, until, at their first public exhibition on June 5, 1783, the bag had become over 35 feet in diameter. On this occasion, it rose to a height of between 900 and 1,000 feet, but the hot air was gradually escaping, and at the end of ten minutes the balloon fell to the ground.

The Montgolfiers then went to Paris, where, after suffering the loss of a paper balloon by rain, they sent up a waterproofed linen one carrying a sheep, a duck, and a rooster in a basket. A rupture in the linen caused the three unwilling aeronauts to make a landing at the end of about ten minutes. The Montgolfiers received great honor, and small balloons of this type became a popular fad. One of these balloons is shown in Fig. 3, making an ascension.

Rozier. The first man to go up in a balloon was Rozier, who ascended in a captive balloon to a height of about 80 feet, in the latter part of the year 1783. Later, in company with a companion, he made a voyage in a free balloon, remaining in the air about half an hour. In these balloons, the air within was kept hot by means of a fire carried in a pan immediately below the mouth of the bag, as shown in Fig. 4. Accidents were numerous on account of the fabric becoming ignited from the fire in the pan.

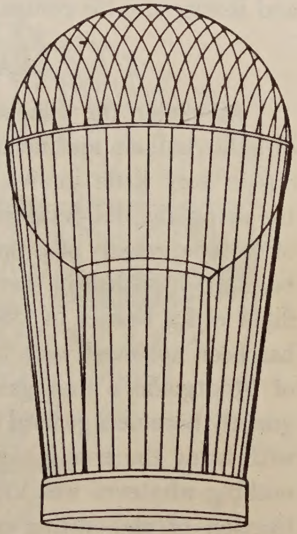

Fig. 4. Rozier Hot-Air Balloon

Improvements by Charles. The physicist, Charles, was working along these lines at the same time. He coated his balloon with a rubber solution to close up the pores, and was thereby enabled to substitute hydrogen for the hot air. Shortly after the Montgolfiers' first public exhibition, Charles sent up his balloon for the benefit of the *Academie des Sciences* in Paris. The balloon, which weighed about 19 pounds, ascended rapidly in the air and disappeared in the clouds, where it burst and fell in a suburb of the city. The impression produced upon the peasants at seeing it fall from the heavens was hardly different from what could be expected. They believed it to be of devilish origin, and immediately tore it into shreds. Charles subsequently built a large balloon quite similar to those in use today. A net was used to support the basket, and a valve, operated by means of ropes from the basket, was arranged at the top to permit the gas to escape as desired.

The Balloon Successful. The English Channel was first crossed in 1785. Blanchard, an Englishman, and Jeffries, an American, started from Dover on January 7 in a balloon equipped with wings and oars. After a very hazardous voyage, during which they had to cast overboard everything movable to keep from drowning, they landed in triumph on the French coast.

An attempt to duplicate this feat was made shortly afterward by Rozier. He constructed a balloon filled with hydrogen, below which hung a receiver in which air could be heated. He hoped to replace by the hot air the losses due to leakage of hydrogen. Soon after the start the balloon exploded, due to the escaping gas reaching the fire, and Rozier and his companion were dashed on the cliffs and killed.

EARLY DIRIGIBLES

Meusnier the Pioneer. The fact that the invention of the dirigible balloon and means of navigating it were almost simultaneous is very little known today and much less appreciated. Like the aeroplane, its development was very much retarded by the lack of suitable means of propulsion, and the actual history of what has been accomplished in this field dates back only to the initial circular flight of La France in 1885. Still the principles upon which success has been achieved were laid down within a year of the appearance of Montgolfier's first gas bag. Lieutenant Meusnier, who subsequently became a general in the French army, must really be credited with being the true inventor of aerial navigation. At a time when nothing whatever was known of the science, Meusnier had the distinction of elaborating at one stroke all the laws governing the stability of an airship, and calculating correctly the conditions of equilibrium for an elongated balloon, after having strikingly demonstrated the necessity for this elongation. This was in 1784 and Meusnier's designs and calculations are still preserved in the engineering section of the French War Office in the form of drawings and tables.

But as often proved to be the case in other fields of research, his efforts went unheeded. How marvelous the establishment of these numerous principles by one man in a short time really is, can be appreciated only by noting the painfully slow process that has been necessary to again determine them, one by one, at considerable intervals and after numerous failures. Through not following the lines which he laid down, aerial navigation lost a century in futile groping about; in experiments absolutely without method or sequence.

Meusnier's designs covered two dirigible balloons and that he fully appreciated the necessity for size is shown by the dimensions of the larger, which unfortunately was never built. This was to be 260 feet long by 130 feet in diameter, in the form of an ellipse, the elongation being exactly twice the diameter. In other words, a perfect ellipsoid, which was a logical and, in fact, the most perfect development of the spherical form. Although increased knowledge of wind resistance and the importance of the part it plays has proved his relative dimensions to be faulty, a study of the principal features of his machine shows that he anticipated the present-day dirigible of the most successful type at practically every point, barring, of course, the motive power, as there was absolutely nothing available in that day except human effort. As the latter weighs more than one-half ton per horse-power, it goes without saying that Meusnier's balloon would have been dirigible only in a dead calm.

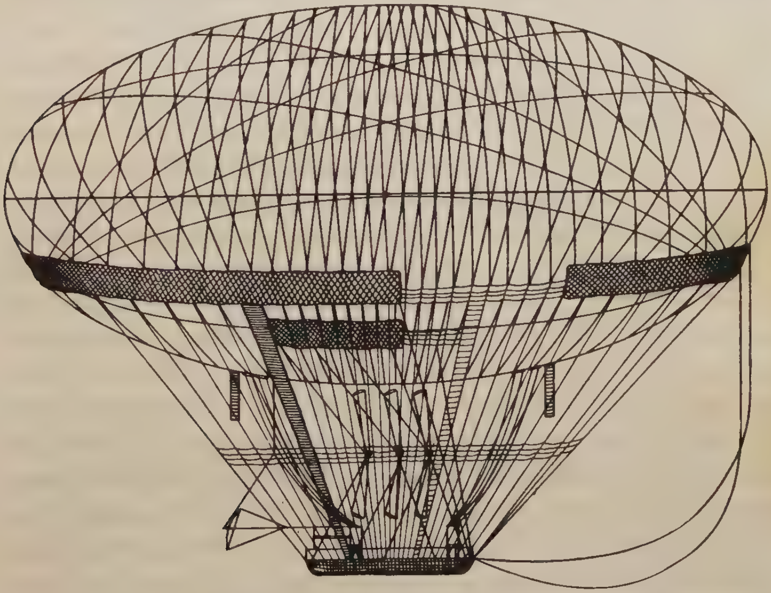

Fig. 5. Meusnier Dirigible Balloon

He adopted the elongated form, conceived the girth fastening, the triangular or indeformable suspension, the air balloonet and its pumps, and the screw propeller, all of which are to be found in the dirigibles of present-day French construction, Fig. 5. It need scarcely be added that the French have not only devoted a greater amount of time and effort to the development of the dirigible than any other nation, but have also met with the greatest success in its use. It was not until 1886, or more than a century after Meusnier had first elaborated those principles, that their value became known. They were set forth by Lieutenant Letourne, of the French engineers, in a paper presented to the *Academie des Sciences* by General Perrier.

In one form or another, the salient features of Meusnier's dirigible will be found embodied in the majority of attempts of later days. His large airship was designed to consist of double envelope, the outer container of which was to provide the strength necessary, and it was accordingly reinforced by bands. The inner envelope was to provide the container for the gas and was not called upon to support any weight. This inner bag or balloon proper was designed to be only partially inflated and the space between the two was to be occupied by air which could be forced into it at two points at either end, by pumps, so as to maintain the pressure on the gas bag uniform regardless of the expansion or contraction of its contents. Here in principle was the air balloonet of today. Instead of employing a net to hang the car from the outer envelope, the former was attached by means of a triangular suspension system fastened to a heavy rope band, or girth, encircling the outer envelope. At the three points where the lifting rope members met, a shaft running the length of the car and carrying what Meusnier described as "revolving oars" was installed. These constituted the prototype of the screw propeller, invented for aerial navigation at a time long antedating the use of steam for marine use. Thus he devised: (1) The air balloonet to husband the gas supply and thus prevent the deformation of the outer container or support, as well as to provide stability; (2) the triangular suspension to attain longitudinal stability; and (3) the screw propeller for propulsion, beside selecting the proper location for the latter.

PROBLEMS OF THE DIRIGIBLE

Ability to Float. If ability to rise in the air depended merely upon a knowledge of the principle that made it possible, it undoubtedly would have been accomplished many centuries ago. As already mentioned, Archimedes established the fact that a body upon floating in a fluid displaces an amount of the latter equal in weight to the body itself, and upon this theory was formulated the now well-known law, that every body plunged into a fluid is subjected by this fluid to a pressure from below, equivalent to the weight of the fluid displaced by the body. Consequently, if the weight of the latter be less than that of the fluid it displaces, the body will float. It is by reason of this that the iron ship floats and the fish swims in water. If the weight of the body and the displaced water be the same, the body will remain in equilibrium in the water at a certain level, and if that of the body be greater, it will sink. All three of these factors are found in the fish, which, with the aid of its natatory gland, can rise to the surface, sink to the bottom, or remain suspended at different levels. To accomplish these changes of specific gravity, the fish fills this gland with air, dilating it until full, or compressing and emptying it. In this we find a perfect analogy to the air balloonet of the dirigible, which serves the same purposes. The method by which lifting power is obtained in the dirigible is exactly the same as in the case of the balloon.

But once in the air, a balloon is, to all intents and purposes, a part of the atmosphere. There is absolutely no sensation of movement, either vertically or horizontally. The earth appears to drop away from beneath and to sweep by horizontally, and regardless of how violently the wind may be blowing, the balloon is always in a dead calm because it is really part of the wind itself and is traveling with it at exactly the same speed. If it were not for the loss of lifting power through the expansion and contraction of the gas, making it necessary to permit its escape in order to avoid rising to inconvenient heights on a very warm day, and the sacrifice of ballast to prevent coming to earth at night, the ability of a balloon to stay up would be limited only by the endurance of its crew and the quantity of provisions it was able to transport. As the use of air balloonets in the dirigible takes care of this, the question of lifting power presents no particular difficulty. It is only a matter of providing sufficient gas to support the increased weight of the car, motor and its accessories, and the crew of the larger vessel, with a factor of safety to allow for emergencies, in order to permit of staying in the air long enough to make a protracted voyage.

Air Resistance vs. Speed. Unless a voyage is to be governed in its direction entirely by the wind, the dirigible must possess a means of moving contrary to the latter. The moment this is attempted, resistance is encountered, and it is this resistance of the air that is responsible for the chief difficulties in the design of the dirigible. To drive it against the wind, it must have power; to support the weight of the motor necessary, the size of the gas bag must be increased. But with the increase in size, the amount of resistance is greatly multiplied and the power to force it through the air must be increased correspondingly. The law is approximately as follows:

Where the surface moves in a line perpendicular to its plane, the resistance is proportional to the extent of the surface, to the square of the speed with which the surface is moved through the air, and to a coefficient, the mean value of which is 0.125.

This coefficient is a doubtful factor, the figure given having been worked out years ago in connection with the propulsion of sailing vessels. Its value varies according to later experimenters between .08 and .16, the mean of the more recent investigations of Renard, Eiffel, and others who have devoted considerable study to the matter, being .08. This is dwelt upon more in detail under "Aerodynamics" and it will be noted that the values of the coefficient K, given here, do not agree with those stated in that article. They serve, however, to illustrate the principles in question.

In accordance with this law, doubling the speed means quadrupling the resistance of the air. For instance, a surface of 16 square feet moving directly against the air at a speed of 10 feet per second will encounter a resistance of 16×100 (square of the speed) $\times 0.125 = 200$ pounds pressure. Doubling the speed, thus bringing it up to 20 feet per second, would give the equation $16 \times 400 \times 0.125 = 800$ pounds pressure, or with the more recent value of the coefficient of .08, 512 pounds pressure. The first consideration is accordingly to reduce the amount of surface moving at right angles. The resistance of a surface having tapering sides which cut through or divide the molecules of air instead of allowing them to impinge directly upon it, is greatly diminished; hence, Meusnier's principle of elongation. If we take the same panel presenting 16 square feet of surface and build out on it a hemisphere, its resistance at a speed of 10 feet per second will be exactly half, or a pressure of 100 pounds.

By further modifying this so as to represent a sharp point, or acute-angled cone, it will be 38 pounds. There could accordingly be no question of attempting to propel a spherical balloon.

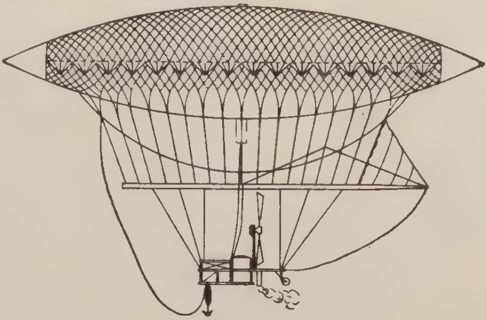

Fig. 6. Giffard Dirigible

It is necessary to select a form that presents as small a surface as possible to the air as the balloon advances, while preserving the maximum lifting power. But experience has strikingly demonstrated the analogy between marine and aerial practice—not only is the shape of the bow of the vessel of great importance but, likewise, the stern. The profile of the latter may permit of an easy reunion of the molecules of air separated by the former, or it may allow them to come together again suddenly, clashing with one another and producing disturbing eddies just behind the moving body. To carry the comparison with a marine vessel a bit further, the form must be such as to give an easy "shear," or sweep from stem to stern.

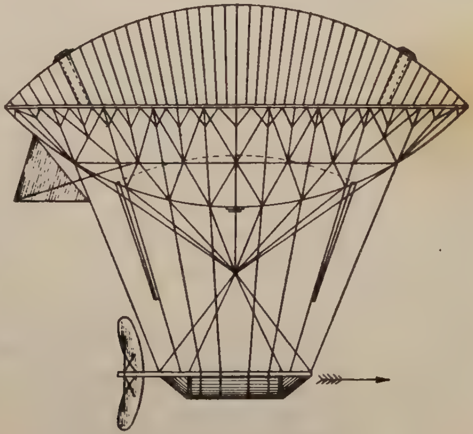

Fig. 7. De Lôme Dirigible

That early investigators appreciated this is shown by the fact that Giffard in 1852, Fig. 6, De Lôme in 1872, Fig. 7, Tissandier in 1884, and Santos-Dumont in his numerous attempts, adopted a spindle-shaped or "fusiform" balloon. In other words, their shape, equally pointed at either end, was symmetrical in relation to their central plan. However, that the shape best adapted to the requirements of the bow did not serve equally well for the stern, was demonstrated for the first time by Renard, to whom credit must be given for a very large part of the scientific development of the dirigible. Almost a century earlier, Marey-Monge had laid down the principle that to be successfully propelled through the air, the balloon must have "the head of a cod and the tail of a mackerel." Nature exemplifies the truth of this in all swiftly moving fishes and birds. Renard accordingly adopted what may best be termed the "pisciform" type, viz, that of a dissymmetrical fish with the larger end serving as the bow; and the performances of the Renard, Lebaudy, and Clement-Bayard airships have shown that this is the most advantageous form.

The pointed stern prevents the formation of eddies and the creation of a partial vacuum in the wake which would impose additional thrust on the bow. Zeppelin has disregarded this factor by adhering to the purely cylindrical form with short hemispherical bow and stern, but it is to be noted that while other German investigators originally followed this precedent, they have gradually abandoned it, owing to the noticeable retarding effect.

Critical Size of Bag. Next in importance to the best form to be given the vessel, is the most effective size—something which has a direct bearing upon its lifting power. This depends upon the volume, while the resistance is proportional to the amount of surface presented. Greater lifting power can accordingly be obtained by keeping the diameter down and increasing the length. But the resistance is also proportionate to the square of the speed, while the volume, or lifting power, varies as the cube of the dimensions of the container, so that in doubling the latter, the resistance of the vessel at a certain speed is increased only four times while its lifting capacity is increased eight times. Consequently the larger dirigible is very much more efficient than the smaller one since it can carry so much more weight in the form of a motor and fuel in proportion to its resistance to the air. As an illustration of this, assume a rectangular container with square ends 1 foot each way and 5 feet long. Its volume will be 5 cubic feet and if the lifting power of the gas be assumed as 2 pounds per cubic foot, its total lifting power will be 5 pounds. If a motor weighing exactly 5 pounds per horse-power be assumed, it will be evident that the motor which such a balloon could carry would be limited to 1 horse-power, neglecting the weight of the container.

Double these dimensions and the container will then measure 2×2×10 feet, giving a volume of 40 cubic feet, and a lifting power, on the basis already assumed, of a motor capable of producing 8 horse-power, and this without taking into consideration that as the size of the motor increases, its weight per horse-power decreases. The balloon of twice the size will thus have a motor of 8 horse-power to overcome the resistance of the head-on surface of 4 square feet, or 2 horse-power per square foot of transverse section, whereas the balloon of half the size will have only 1 horse-power per square foot of transverse section. It is, accordingly, not practicable to construct small dirigibles such as the various airships built by Santos-Dumont for his experiments, while, on the other hand, there are numerous limitations that will be obvious, restricting an increase in size beyond a certain point, as has been shown by the experience of the various Zeppelin airships.

To make it serviceable, what Berget terms the "independent speed" of a dirigible, *i.e.*, its power to move itself against the wind, must be sufficient to enable it to travel under normally prevailing atmospheric conditions. These naturally differ greatly in different countries and in different parts of the same country. Where meteorological tables showed the prevailing winds in a certain district to exceed 15 miles an hour throughout a large part of the year, it would be useless to construct an airship with a speed of 15 miles an hour or less for use in that particular district, as the number of days in the year in which one could travel to and from a certain starting point would be limited. This introduces another factor which has a vital bearing upon the size of the vessel. Refer to the figures just cited and assume further that by doubling the dimensions and making the airship capable of transporting a motor of 8 horse-power, it has a speed of 10 miles an hour. It is desired to double this. But the resistance of the surface presented increases as the square of the speed. Hence, it will not avail merely to double the power of the motor. Experience has demonstrated that the power necessary to increase the speed of the same body, increases in proportion to the cube of the speed, so that instead of a 16-horse-power motor in the case mentioned, one of 64 horse-power would be needed. There are, accordingly, a number of elements that must be taken into consideration when determining the size as well as the shape of the balloon.

Fabric and Color. As the gas is frequently under considerable pressure when the balloon expands under the influence of the suns' heat, a great deal of experiment has been necessary to find the best class of fabric for the making of the envelope. Under the pressure, an ordinary fabric would stretch and permit the escape of a large percentage of the gas. It has been found impossible to weave any fabric that will be close enough to hold hydrogen under pressure, so that recourse is had to a combination of cloth and rubber. The cloth is an extremely fine weave of cotton even lighter and closer than the best of racing yacht duck, and it is combined with rubber under heavy pressures. Three layers of this rubberized fabric are cemented together to form what is known as "balloon cloth," which is about as impermeable a material as can be made without involving undue weight. The necessity of using rubber in it has introduced a complication, it having been found by experiment that rubber is strongly attacked by the ultra-violet rays of sunlight, which probably accounts for the fact that balloon envelopes are usually found more or less damaged after a high ascension, the influence of these rays being much greater at the higher altitudes. To offset this, experiments are being made in the introduction of coloring matter in the fabric, some envelopes having been dyed yellow and others red. M. Reynaud, who has conducted a series of experiments illustrating the damage suffered by rubber when subjected to the light of a mercury vapor lamp with a quartz tube, which is a powerful source of such rays, recommends red as absorbing both the violet and blue rays.

Static Equilibrium. Having settled upon the size and shape, there must be an appropriate means of attaching the car to carry the power plant, its accessories and control, and the crew. While apparently a simple matter, this involves one of the most important elements of the design—that of stability. A long envelope of comparatively small diameter being necessary for the reasons given, it is essential that this be maintained with its axis horizontal. In calm air, the balloon, or container, is subjected to the action of two forces: One is its weight, applied to the center of gravity of the system formed by the balloon, its car, and all the supports; the other is the thrust of the air, applied at a point known as the center of thrust and which will differ with different designs, according as the car is suspended nearer or farther away from the balloon. If the latter contained only the gas used to inflate it, with no car or other weight to carry, the center of gravity and the center of thrust would coincide, granting that the weight of the envelope were negligible. As this naturally can not be the case, these forces are not a continuation of each other. But as they must necessarily be equal if the balloon is neither ascending nor descending, it follows that they will cause the balloon to turn until they are a continuation of each other, and in the case of a pisciform balloon, this will cause it to tilt downward. Like a ship with too much cargo forward, it would be what sailors term "down at the head."

As this would be neither convenient nor compatible with rapid propulsion, it must be avoided by distributing the weight along the car in such a manner that when the balloon is horizontal, the forces represented by the pressure above and the weight below, must be in the same perpendicular. This is necessary to insure *static equilibrium*, or a horizontal position while in a state of rest. To bring this about, the connections between the car and the balloon must always maintain the same relative position, which is further complicated by the fact that they must be flexible at the same time.

Longitudinal Stability. But the *longitudinal stability* of the airship as a whole must be preserved, and this also involves its *stability of direction*. Its axis must be a tangent to the course it describes, if the latter be curvilinear, or parallel with the direction of this course where the course itself is straight. This is apparently something which should be taken care of by the rudder, any tendency on the part of the airship to diverge from its course being corrected by the pilot. But a boat that needed constant attention to the helm to keep it on its course would be put down as a "cranky"—in other words, of faulty design in the hull. A dirigible having the same defect would be difficult to navigate, as the rudder alone would not suffice to correct this tendency in emergencies. Stability of direction is, accordingly, provided for in the design of the balloon itself, and this is the chief reason for adopting the form of a large-headed and slender-bodied fish, as already outlined. This brings the center of gravity forward and makes of the long tail an effective lever which overcomes any tendency of the ship to diverge from the course it should follow, by causing the resistance of the air itself to bring it back into line. However, the envelope of the balloon itself would not suffice for this, so just astern of the latter, "stabilizing surfaces" are placed, consisting of vertical planes fixed to the envelope. These form the keel of the dirigible and are analogous to the keel of the ship. Stability of direction is thus obtained naturally without having constant recourse to the rudder, which is employed only to alter the direction of travel.

The comparison between marine and aerial navigation must be carried even further. These vertical planes, or "keel," prevent rolling; it is equally necessary to avoid pitching—far more so than in the case of a vessel in water. So that while the question of stability of direction is intimately connected with longitudinal stability, other means are required to insure the latter. The airship must travel on an "even keel," except when ascending or descending, and the latter must be closely under the control of the pilot, as otherwise the balloon may incline at a dangerous angle. This shows the importance of an unvarying connection between the car and the envelope to avoid defective longitudinal stability. Assume, for instance, that the car is merely attached at each end of a single line. The car, the horizontal axis of the balloon, and the two supports would then form a rectangle. When in a state of equilibrium the weight and the thrust are acting in the same line. Now suppose that the pilot desires to descend and inclines the ship downward. The center of gravity is then shifted farther forward and the two forces are no longer in line.

But as the connections permit the car to swing in a vertical plane, they permit the latter to move forward and parallel with the balloon, thus forming a parallelogram instead of a rectangle. This causes the center of gravity to shift even farther, and as one of the most serious causes of longitudinal stability is the movement of the gas itself, it would also rush to the back end and cause the balloon to "stand on its head." As the tendency of the gas is thus to augment any inclination accidentally produced, the vital necessity of providing a suspension that is incapable of displacement with relation to the balloon is evident. Here is where the importance of Meusnier's conception of the principle of triangular suspension comes in. Instead of being merely supported by direct vertical connections with the balloon, the ends of the car are also attached to the opposite ends of the envelope, forming opposite triangles. This gives an unvarying attachment, so that when the balloon inclines, the car maintains its relative position, and the weight no longer being a prolongation of the thrust, the two forces tend to pull each other back in the same line, or, in other words, to "trim ship." Granting a proper form of balloon or gas container to start with, it will be evident that due attention to the principles just outlined will produce a vessel that will not only hold to its course without fatiguing the pilot, but that will also not be subject to a tendency to pitch or roll. As air is much easier to displace than water, it will be evident that either of these characteristics would be far more dangerous in an airship than in a marine vessel and they would naturally be sufficient to condemn it, even in the absence of other shortcomings.

Dynamic Equilibrium. In addition to being able to preserve its static equilibrium and to possess proper longitudinal stability, the successful airship must also maintain its *dynamic equilibrium*—the equilibrium of the airship in motion. This may be made clear by referring to the well-known expedients adopted to navigate the ordinary spherical balloon. To rise, its weight is diminished by gradually pouring sand from the bags which are always carried as ballast. To descend, it is necessary to increase the total weight of the balloon and its car, and the only method of accomplishing this is to permit the escape of some of the gas, the specific lightness of which constitutes the lifting power of the balloon. As the gas escapes, the thrust of the air on the balloon is decreased and it sinks—the ascensional effort diminishing in proportion to the amount of gas that is lost. The balloon, or the container itself, being merely a spherical bag, on the upper hemispherical half of which the net supporting the car presses at all points, the question of deformation is not a serious one. Before it assumed proportions where the bag might be in danger of collapsing, the balloon would have had to come to earth through lack of lifting power to longer sustain it. Owing to its far greater size, as well as to the form of the surface which it presents to the air pressure, such a crude method is naturally not applicable to the dirigible.

Dynamic equilibrium must take into account not only its weight and the sustaining pressure of the air, but also the resistance of the air exerted upon its envelope. This resistance depends upon the dimensions and the shape of that envelope, and in calculations the latter is always assumed to be invariable. Assume, for instance, that to descend the pilot of a dirigible allowed some of the hydrogen gas to escape. As the airship came down, it would have to pass through strata of air of constantly increasing pressure as the earth is approached. The reason for this will be apparent as the lower strata bear the weight of the entire atmosphere above them. The confined gas will no longer be sufficient to distend the envelope, the latter losing its shape and becoming flabby. As the original form is no longer retained, the center of resistance of the air will likewise have changed together with the center of thrust, and the initial conditions will no longer obtain. But as the equilibrium of the airship depends upon the maintenance of these conditions, it will be lost if they vary.

Function of Balloonets. In the function of balloonets is realized the importance of the principle established by Meusnier. It was almost a century later before it was rediscovered by Dupuy de Lôme in connection with his attempts to make balloons dirigible. That the balloon must always be maintained in a state of perfect inflation has been pointed out. But gas is lost in descents and to a certain extent, through the permeability of the envelope. Unless it is replaced, the balloon will be only partially inflated. In view of the great volume necessary, it requires no explanation to show that it would be impossible to replace the gas itself by fresh hydrogen carried on the car. It would have to be under high pressure and the weight of the steel cylinders as well as the number necessary to transport a sufficient supply would be prohibitive. Hence, Meusnier conceived the idea of employing air. But this could not be pumped directly into the balloon to mix with the hydrogen gas, as the resulting mixture would not only still be as inflammable as the former alone, but it would also contain sufficient oxygen to create a very powerful and infinitely more dangerous explosive. This led to the adoption of the *air balloonet*.

In principle the balloonet consists of dividing the interior of the envelope into two cells, the larger of which receives the light gas while the smaller is intended to hold air and terminates in a tube extending down to a pump in the car. In other words, a fabric partition adjacent to the lower part of the envelope inside and subject to deformation at will. In actual practice it consists of a number of independent cells of this kind, longitudinally disposed along the lower half of the interior of the envelope, as in the case of Wellman's "America," which was equipped with a number of air balloonets, the location of which may be noted by referring to the illustrations of this airship, Fig. 19.

When the balloon is completely inflated with hydrogen, as at the beginning of an ascent, these balloonets lie flat against the lower part of the envelope, exactly like a lining. As the airship rises, the gas expands owing to the reduction in atmospheric pressure at a higher altitude, as well as to the influence of heat. With the increase in pressure, uniform inflation is maintained by the escape of a certain amount of gas through the automatic valves provided for the purpose. Unless this took place, the internal pressure might assume proportions placing the balloon in danger of blowing up. To avoid this, a pressure gauge communicating with the gas compartment is one of the most important instruments on the control board of the car, and should its reading indicate a failure of the automatic valves, the pilot must reduce the pressure by operating a hand valve. But as the car descends, the increased external pressure causes a recontraction of the gas until it no longer suffices to fill the envelope. To replace the loss the air pumps are utilized to force air into the air balloonets until the sum of the volumes of gas and air in the different compartments equals the original volume. In this manner, the initial conditions, upon which the equilibrium of the airship is based, are always maintained.

This is not the only method of correcting for change in volume, nor of maintaining the longitudinal stability of the whole fabric, the importance of which has already been detailed, but experience has shown that it is the most practical. It is possible to give the balloon a rigid frame over which the envelope is stretched and to attach the car by means of a rigid metal suspension, as in the various Zeppelin airships, or to take it semi-rigid, as in the Gross, another German type in which Zeppelin's precedent was followed only in the case of the suspension. To prevent deformation by this means, the balloon is provided with an absolutely rigid skeleton of aluminum tubes. This framing is in the shape of a number of uniform cylindrical sections, or gas compartments, each one of which accommodates an independent balloon, while over the entire frame a very strong but light fabric constituting the outer or protecting envelope is stretched taut. The idea of the numerous independent balloons is to insure a high factor of safety as the loss of the entire contents of two or three of them through accident would not dangerously affect the lifting power of the whole. Apart from its great expense, the rigid nature of this construction makes it a delicate thing to handle on the ground, as witness the numerous wrecks that have attended the landings of the huge, non-flexible mass. To minimize this risk in starting, its "home port" had to be made in the form of a floating shed, anchored only at one end so that the ship could always emerge to "leeward."

The system of air balloonets has accordingly been adopted by every other designer, in variously modified forms, as illustrated by the German dirigible Parseval, in which but two air bags were employed; one at either end. They were interconnected by an external tube to which the air-pump discharge was attached, and were also operated by a counterbalancing system inside the gas bag, by means of which the inflation of one balloonet, as the after one, for example, caused the collapse of the other.

Influence of Fish Form of Bag. But a condition of dynamic equilibrium can not be obtained with the combined aid of the precautions already noted to secure longitudinal stability and that of the air balloonet in maintaining uniform inflation. Why this is so will be clear from a simple example. If a simple fusiform or spindle-shaped balloon be suspended in the air in a horizontal plane, the axis of which passes through its center of gravity, it would be practically pivoted on the latter and would be extremely sensitive to influences tending to tilt it up or down. It would be in a state of "indifferent" longitudinal equilibrium. As long as the axis of the balloon remains horizontal and the air pressure is coincident with that axis, it will be in equilibrium, but an equilibrium essentially unstable. Experiment proves that the moment the balloon inclines from the horizontal in the slightest degree, there is a strong tendency for it to revolve about its center of gravity until it stands vertical to the air current, or is standing straight up and down. This, of course, refers to the balloon alone without any attachments. Such a tendency would be fatal, amounting as it does to absolute instability.

If instead of symmetrical form, tapering toward both ends, a pisciform balloon be tried, it will still evidence the same tendency, but in greatly diminished degree. This is not merely the theory affecting its stability but represents the findings of Col. Charles Renard, who undoubtedly did more to formulate the exact laws governing the stability of a dirigible than any other investigator in this field. His data is the result of a long and methodically carried out series of experiments. In the case of the pisciform balloon, the disturbing effect is due in unequal degree, to the diameter of the balloon and its inclination and speed, whereas the steadying effect depends upon the inclination and diameter, but not on the speed. The disturbing effect, therefore, depends solely on the speed and augments very rapidly as the speed increases. It will, accordingly, be apparent that there is a certain speed for which the two effects are equal, and beyond which the disturbing influence, depending on speed, will overcome the steadying effect.

To this rate of travel, Renard applied the term "critical speed," and when this is exceeded the equilibrium of the balloon becomes unstable. To obtain this data, keels of varying shapes and dimensions were submitted to the action of a current of air, the force of which could be varied at will. In the case of the La France, the first fish-shaped dirigible, the critical speed was found to be 10 meters, or approximately 39 feet per second, a speed of 21.6 miles per hour, and a 24-horse-power motor suffices to drive the airship at this rate of travel. But the internal combustion motor is now so light that a dirigible of this type could easily lift a motor capable of generating 80 to 100 horse-power. With this amount of power, its theoretic speed would be 50 per cent greater, or 33 miles an hour. But this could not be accomplished in practice as long before it was reached the stability would become precarious. As Colonel Renard observed in the instance just cited, "If the balloon were provided with a 100-horse-power motor, the first 24 horse-power would make it go and the other 76 horse-power would break our necks."

Steadying Planes. It is accordingly necessary to adopt a further expedient to insure stability. This takes the form of a system of rigid planes, both vertical and horizontal, located in the axis of the balloon and placed a considerable distance to the rear of the center of gravity. With this addition, the resemblance of the after end of the balloon to the feathering of an arrow is apparent, while its purpose is similar to that of the latter. For this reason, these steadying planes have been termed the *empennage*, which is the French equivalent of "arrow feathering," while its derivative *empennation* is employed to describe the counteraction of this disturbing effect. In the La France, which measured about 230 feet in length by 40 feet in diameter, the area of the planes required to accomplish this was 160 square feet, and the planes themselves were placed almost 100 feet to the rear of the center of gravity. By referring to the illustrations of the various French airships, the various developments in the methods of accomplishing this will be apparent.

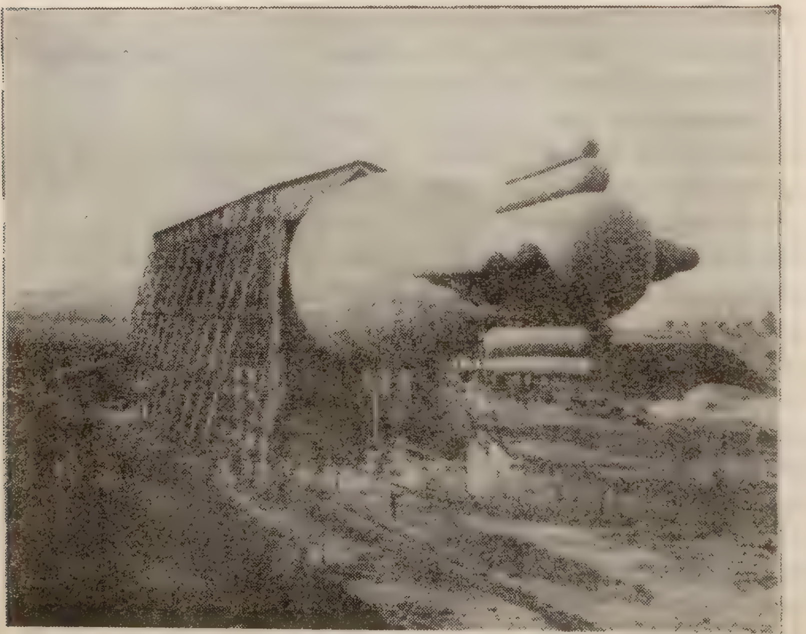

Fig. 8. La Ville de Paris Showing Balloonets

In the Lebaudy balloon, it took the form of planes attached to the framework between the car and the balloon. In La Patrie and La Republique, the resemblance to the feathered arrow was completed by attaching four planes in the form of a cross directly to the stern of the balloon itself. But as weight, no matter how slight, is a disturbing factor at the end of a long lever, such as is represented by the balloon, Renard devised an improvement over these method by conceiving the use of hydrogen balloonets as steadying planes. This idea was first embodied in La Ville de Paris, Fig. 8, in the form of cylindrical balloonets, and as conical balloonets on the Clement-Bayard. These balloonets communicate with the gas chamber proper of the balloon and consequently exert a lifting pressure which compensates for their weight, so that they no longer have the drawback of constituting an unsymmetrical supplementary load. Zeppelin provides for dynamic stability by the use of an extremely long car along the length of which a considerable weight in concentrated form may be displaced to counteract any tendency to tilt. This, however, has the disadvantage of placing a great and comparatively useless additional burden on the lifting power of the car, and is neither simple nor automatic in its action, as is the *empennage*.

Location of Propeller. The final factor of importance in the design of the successful dirigible, is the proper location of the propulsive effort with relation to the balloon. Theoretically, this should be applied to the axis of the balloon itself, as the latter represents the greater part of the resistance offered to the air. At least one attempt to carry this out in practice resulted disastrously, that of the Brazilian airship Pax, while the form adopted by Rose in which the propeller was placed between the twin balloons in a plane parallel with their horizontal axes, was not a success. In theory, the balloon offers such a substantial percentage of the total resistance to the air that the area of the car and the rigging were originally considered practically negligible by comparison. Actually, however, this is not the case. Calculation shows that in the case of any of the typical French airships mentioned, the sum of the surface of the suspending rigging alone is easily the equivalent of 2 square meters, or about 21 square feet, without taking into consideration the numerous knots, splices, pulleys, and ropes employed in the working of the vessel, air tubes communicating with the air balloonets, and the like. Add to this equivalent area that of the passengers, the air pump, other transverse members and exposed surfaces, and the total will be found equivalent to a quarter or even a third of the transverse section of the balloon itself.

To insure the permanently horizontal position of the ship under the combined action of the motor and the air resistance, a position of the propeller at a point about one-third of the diameter of the balloon below its horizontal axis will be necessary. Without employing a rigid frame like that of the Zeppelin and the Pax, however, such a location of the shaft is a difficult matter for constructional reasons. Consequently, it has become customary to apply the driving effort to the car itself, as no other solution of the problem is apparent. This accounts for the tendency common in the dirigible to "float high forward," and this tilting becomes more pronounced in proportion to the distance the car is hung beneath the balloon. The term "deviation" is employed to describe this tilting effect produced by the action of the propeller. Conflicting requirements are met with in attempting to reduce this by bringing the car closer to the balloon as this approximation is limited by the danger of operating the gasoline motor too close to the huge volume of inflammable gas. The importance of this factor may be appreciated from the fact that if the car were placed too far from the balloon, the propulsive effect would tend to hold the latter at an angle without advancing much, owing to the vastly increased air resistance of the much larger surface thus presented. The best solution of the problem has been found by placing the motor in the car and driving a shaft located between the car and the balloon by means of a chain.

This has not been very generally followed, however, owing to the different ideas prevailing as to the best location for the propeller itself. In the Ville de Paris and the Clement-Bayard, it is placed at the bow and serves to draw the balloon along. Earlier attempts, such as Giffard's, De Lôme's, and the Tissandier airship, patterned after marine practice by placing it at the stern. The constructor of the Lebaudy and La Patrie adopted the use of two propellers, placed on either side of the car and almost in a line with its center, this also being the case in the design of the America, except that the latter was provided with four screws altogether, two of which were on swiveling joints to allow of their being utilized to either drive the ship ahead, or to assist in its ascent or descent by being driven at right angles to their shaft. Zeppelin also employs four propellers placed along the sides of the car. The United States army dirigible has the screw forward, while the British military airship carries it at the stern of a very short car. On the whole, its location at the bow would appear to offer the greatest advantage, where a single propeller is employed.

Relations of Speed and Radius of Travel. The various factors influencing the speed of a dirigible have already been referred to, but it will be apparent that the radius of action is of equally great importance. It is likewise something that has a very direct bearing upon the speed and, in consequence, upon the design as a whole. It will be apparent that to be of any great value for military or other purposes, the dirigible must possess not only sufficient speed to enable it to travel to any point of the compass under ordinarily prevailing conditions of wind and weather, but it must likewise be able to remain in the air for some time and cover considerable distance under its own power. In fact, one of the chief advantages possessed by the dirigible over the aeroplane at present is its ability to make long-sustained flights, while carrying a comparatively large crew and a great deal of extra weight.

Total Weight per Horse-Power Hour. As is the case in almost every point in the design of the dirigible, conflicting conditions must be reconciled in order to provide it with a power plant affording sufficient speed with ample radius of action. It has already been pointed out that power requirements increase as the *cube of the speed,* making a tremendous addition necessary to the amount of power to obtain a disproportionately small increase in velocity. In this connection thereis a phase of the motor question that has not received the attention it merits up to the present time. The struggle to reduce weight to the attainable minimum has made *weight per horse-power* apparently the paramount consideration—a factor to which other things could be sacrificed. And this is quite as true of the aeroplane motor as those designed for use in the dirigible. But it is quite as important to make the machine go as it is to raise it in the air, so that the question of *total weight per horse-power hour* will undoubtedly come in for much more attention in future, particularly since weight per horse-power appears to have approached so closely the minimum attainable, consistent with a due regard for reliability.

The relative importance of these two factors may be appreciated from the following illustration:

Assume, for instance, a 100 horse-power motor of a total weight of 1,000 pounds, round numbers being chosen merely for the sake of simplicity. The weight per horse-power of such an engine would be 10 pounds. This would not be sufficient data, however, from which the design of a dirigible to employ that motor could be worked out. *Pounds per horse-power* usually refers to a bare engine. The weight of cooling water, lubricants, accessories, and last, but far from least, that of the fuel, must be added. For example, the motor referred to may be assumed to require 1 pound of fuel and lubricant per horse-power per hour to run it at its normal output—*i. e.*, 100 horse-power. This means that it will consume 100 pounds per hour, or for a run of 10 hours, 1,000 pounds, and this weight must be added to that of the motor itself in considering the design from the standpoint of radius of action. On the above basis, 1,000 horse-power hours will be obtainable, and dividing the total weight of motor and supplies (2,000 pounds) by this, would give a weight of 2 pounds per horse-power hour.

This factor depends entirely upon the efficiency of the motor, while *its* weight per horse-power is a question of its construction alone. It requires no abstruse calculations to show that it is quite possible to have the same number of pounds for the weight per horse-power of a very light engine that consumes a great deal of fuel, as it is with a heavy engine that consumes very little. The diminution of the weight per horse-power hour makes possible an increase in the duration of the voyage, which is a very desirable advantage, but as the prime factor is ability to rise, improvement that involves the addition of the weight is closely restricted by the lifting power available, so that radius of action is governed by numerous considerations, as will be seen from the following:

Take a dirigible with a gas capacity of 12,000 cubic feet, equipped with two 60-horse-power motors, giving it a speed of 36 miles per hour. The engines will consume 130 pounds of fuel per hour, and the machine, with 6 passengers, will have sufficient lifting capacity to carry 1,300 pounds of gasoline. This would mean traveling for 10 hours, or 5 hours in each direction, if necessary to return to the starting point as is usually the case. This would mean traveling 180 miles from the start—in other words, the radius of action of this dirigible would be 180 miles. But this is based on traveling at maximum speed for the entire period, disregarding the prevailing winds, the influence of which will be taken up later. War vessels seldom steam for any length of time at full speed, except in emergencies. They run under reduced power, or at a "cruising speed," thus greatly extending their available radius of action. The same thing may be done with the dirigible. By using only one of the motors of the airship in question, the period for which it could travel would be doubled. The propelling power will be then only 60 horsepower. The speed will be divided by the cubic root of 2, bringing it down to approximately 29 miles an hour. But as the single motor will consume only 65 pounds of fuel per hour, it will have 20 hours of travel, or 10 hours to go and 10 to return, so that its radius of action will be 290 miles. The importance of this in the application of aerial navigation to military service will be plain.

Speed is quite as costly in an airship as it is in an Atlantic liner. To double it, the motor power must be multiplied by 8, and the machine must carry 8 times as much fuel. But by cutting the power in half, the speed is reduced only one-fifth. The problem of long voyages in the dirigible is, accordingly, how to reconcile best the minimum speed which will enable it to effectively make way against the prevailing winds, with the reduction in power necessary to cut the fuel consumption down to a point that will insure a long period of running. From the above discussion, it is evident that at least two independent motors should be provided, so that under favorable weather conditions, only one need be employed, while the total power of both could be called upon in emergencies. This was the expedient adopted in the instance of the America, designed to make a 3,000-mile voyage.

Influence of Wind. But the wind is a serious factor that has to be taken into consideration. Radius of action as above illustrated has been based entirely upon traveling in a dead calm. True, where the prevailing wind blew from a certain quarter for a length of time, its favoring influence in going would be neutralized by its resistance in returning, so that the result would be the same, provided the velocity of the wind were not too great to prevent returning at all against it. But with the perversity of inanimate things, the wind may always be in the wrong direction, or seemingly so. Or again, the strong wind which retards progress on the outgoing trip, may die down to a perfect calm when it is time to return, so that the disadvantage of having to travel against it will not be compensated for by extra speed returning. The wind is something with which the aeronaut must always figure, quite as much as the sailor.

TABLE I

Speed* of the Wind for the Vicinity of Paris

Speed of Wind in Feet per Second	Speed of Wind in Miles per Hour	Number of Days per Year when Velocity might be less than given in the first two columns
10	6.8	39
20	13.6	117
30	20.5	197
40	27.3	258
50	34.1	297
60	40.9	323
70	47.7	342
80	54.6	350
90	61.4	354
100	68.2	358
110	75.	361
120	81.8	363
130	88.7	364
140	95.5	364
150	102.3	364
160	109.1	365
170	116.	365
180	122.8	365

*The above speed values are only approximations to the metric quantities.

When the speed of the dirigible is greater than that of the prevailing wind, it may travel in any direction; when it is considerably less, it can travel only with the wind; when it is equal to the speed of the latter, it may travel at an angle with the wind—in other words, tack, as a ship does, utilizing the pressure of the contrary wind to force the ship against it. But as the air does not offer the same hold on it to the hull of the airship, as water does to that of the seagoing ship, the amount of leeway or drift in such a maneuver would doubtless be excessive. This briefly sums up a subject to which many pages are devoted in the textbooks, and it applies quite as much to the aeroplanes as it does to the dirigible.

As the wind has always been a factor of great importance, carefully compiled meteorological tables accurately indicate the winds that are to be expected on the ocean in any part of the globe at different seasons in the year, giving their direction, average strength, or velocity, and the number of days per year on which certain winds may reasonably be looked for. Data of a similar nature is largely lacking with regard to the land, but now that aerial navigation is so prominently to the fore, it will undoubtedly receive the attention it deserves. In fact, this has already been done for the vicinity of Paris, and likewise in several parts of Germany and Sweden, where accurate observations have been made to determine the possibility of employing wind wheels for power purposes. The importance of such tables to the aeronaut will be apparent. Table I is given by Berget as applying to the vicinity of Paris.

It requires only a superficial study of this table to demonstrate that the vicinity of Paris is a favorable district for the navigation of dirigibles of moderate power and speed. Take an airship having a speed of only 22.3 (36 kilometers) miles per hour as an instance of this. The table shows that there are 258 days in a year when the velocity of the wind is less than 40 feet per second. By increasing this to 27.9 miles per hour (45 kilometers), which is the speed of the Clement-Bayard, the Republique, and Le Ville de Paris, it will be evident that such a balloon would be dirigible on an average of 297 days out of the 365, or about ten months out of the twelve. But, as has been shown by the observations made from the Eiffel Tower, the speed of the wind is very much less near the ground than it is at greater altitudes. In the locality in question, observations indicate that the average velocity of the wind the year round, at the level of the house tops, is between 8 and 10 feet per second, while at the top of the tower, or 1,000 feet from the ground, it is 32 feet. To again refer to the table, it will be seen that by giving an airship an independent speed of slightly over 43 miles per hour, it will be navigable on 350 days out of the year, and as the days on which the wind velocity exceeds 80 feet per second are those of bad storms, in which neither the dirigible nor the aeroplane would be an ideal means of transport, the problem where the former is concerned would appear to find its solution in an increase of its speed to this point. To do this and still provide an effective radius of action with the present percentage of efficiency of the average light motor built for aeronautical use is not an easy matter, particularly as the greatly increased air resistance would also involve a much stronger envelope to stand the high pressure. This means added weight and cuts down the lifting power for the same volume, while increasing the latter means greatly augmented air resistance and greater power to attain the same speed.

FRENCH DIRIGIBLES

The First Lebaudy. The interest evidenced by the German War Department in Zeppelin's airship was more than duplicated by that aroused in French military circles by the success of the Lebaudy Brothers. Since 1900 these two brothers had been experimenting with dirigible balloons. Their first dirigible—built by the engineer Juillot—made thirty flights, in all but two of which it succeeded in returning to its starting point. This machine was somewhat similar to the later types built by Santos-Dumont, and carried a 40-horse-power Daimler motor. A speed of 36 feet per second, or about 25 miles per hour, was obtained. During tests in the summer of 1904, the balloon was dashed against a tree and almost entirely destroyed.

Lebaudy 1904. The next year the "Lebaudy 1904" appeared. This was 190 feet long and had a capacity of 94,000 cubic feet of gas. The air bag was divided into three parts and contained 17,600 cubic feet of air. It was supplied with air from a fan driven by the engine, and an auxiliary electric motor and storage battery were carried to drive the fan when the gas engine was not working. The storage battery was also used to furnish electric lights for the airship. A horizontal sail of silk was stretched between the car and the gas bag. This had an area of something over 1,000 square feet, and a sort of keel of silk was stretched below it. A horizontal rudder, shaped like a pigeon's tail, was used at the rear, and immediately behind it were two V-shaped vertical rudders. A small vertical sail was carried, which could be used to assist in guiding the airship. The car was 16 feet long, and was rigidly hung 10 feet below the bag. It was provided with an inverted pyramid of steel tubes meeting at an apex below the car to prevent injury in alighting. Sixty-three ascents were made in 1904 with this balloon, all of them comparatively successful, the longest being a journey of 60 miles in two hours and forty-five minutes. It was then turned over to the War Department as a school ship.

The next year a new and larger balloon, equipped with a more powerful motor was used. Many flights were made in tests for the

French War Department. In some of these, the Lebaudy Brothers were accompanied by the minister of war.

La Patrie. La Patrie was then built for the French government by the Lebaudy Brothers, and was of the same design as their earlier airships. In speed it was nearly equal to Zeppelin's, and its dirigibility was nearly perfect. Fig. 9 shows a view of this airship in flight.

It was 200 feet long, and the 70-horse-power engine drove two propellers. It could carry seven people and one-half ton of ballast. It carried four people at a speed of 30 miles per hour. On its last trip it covered 175 miles in seven hours. A few days afterward, a heavy wind tore it away from its moorings, and it was blown out to sea and lost.

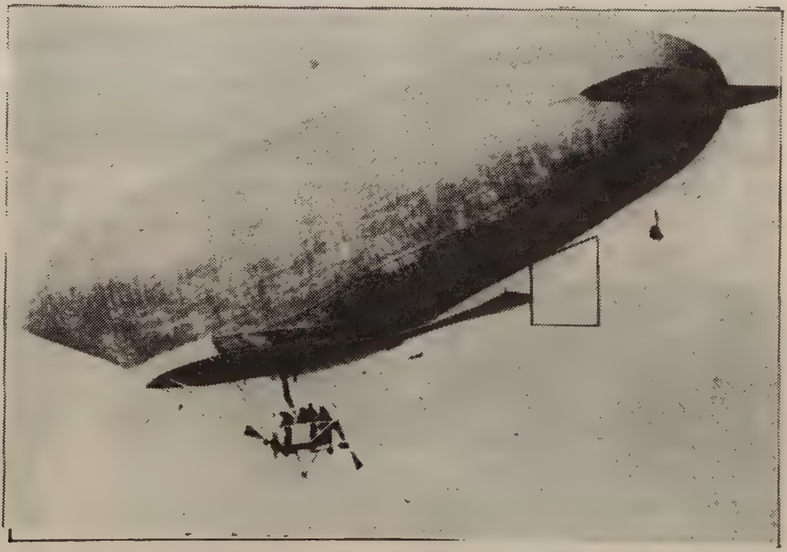

Fig. 9. La Patrie, French War Dirigible

La Republique and Le Jaune. Two more airships of the same type, La Republique and Le Jaune, followed this. These were tried by the French government in 1908, and both proved successful. La Republique is illustrated in Fig. 10. The shape and equipment of the car are shown in Fig. 11. The automobile-type radiator may be seen attached to the side of the car. During a flight in the fall of 1909, a propeller blade broke and was thrown clear through the

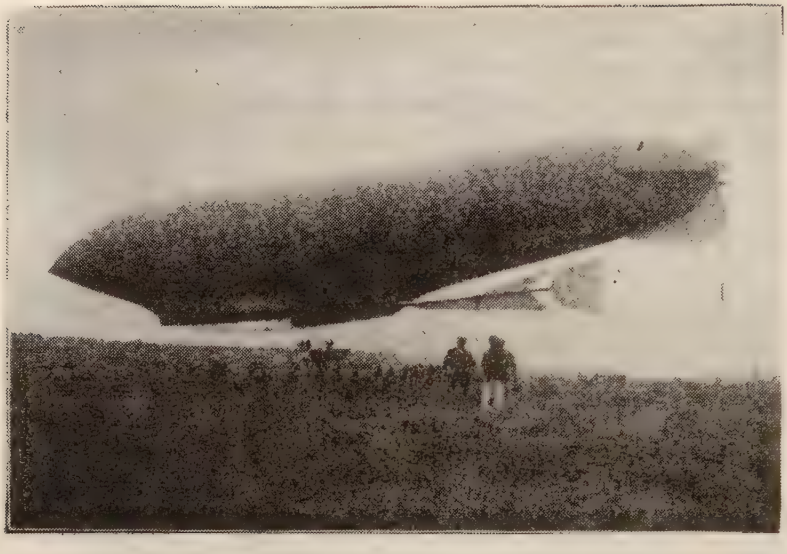

Fig. 10. La Republique, French War Dirigible

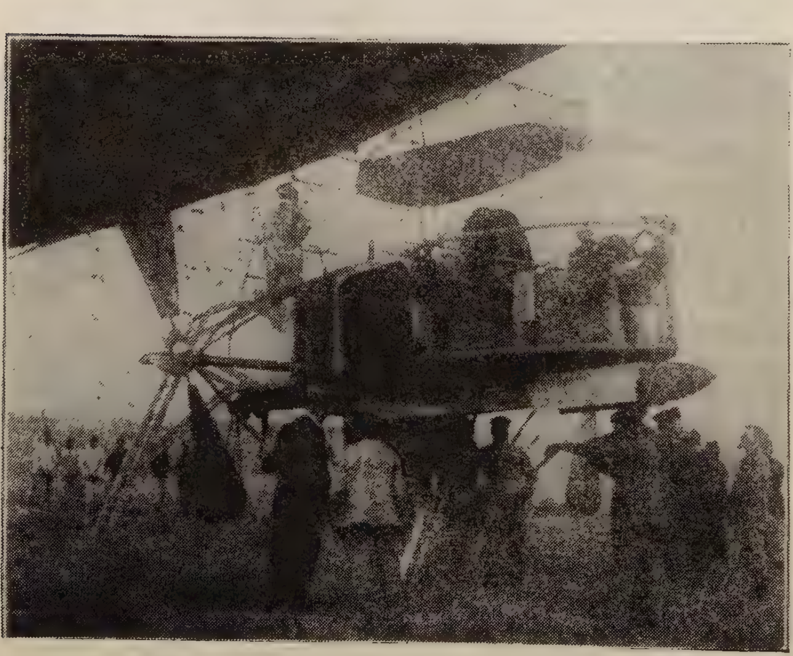

Fig. 11. Car of La Republique

balloon envelope, causing the balloon to fall from a height of 500 feet. The four officers who formed the crew of the dirigible were instantly killed.

The Russian government commissioned the Lebaudy Brothers to build an airship which was to be the nucleus of the Russian air navy. Accordingly, the Russie was built early in 1909, and is a faithful copy of the French La Republique in every respect; a number of others have been delivered to the Russian army since. Trips are in progress at the Lebaudy Airship Works at Moisson.

Portable Airship. For military purposes, an airship should be so constructed as to be easily and quickly packed. A dirigible balloon was built in 1908 by Count de la Vaulx, which could be very easily taken apart for transportation and put together again. The fact that it was capable of carrying only one man was the cause of its limited usefulness.

Clement=Bayard II. The numerous factors that must be considered in the design of a successful dirigible balloon, as well as the many conflicting conditions that must be reconciled, have already been referred to in detail. How these are carried out in practice may best be made clear by a description of what may be considered as an advanced type of dirigible, the Clement-Bayard II, Fig. 12, of French design, and the most successful of the French military air fleet. In fact, the design of this airship incorporates all those features which the experience of aeronauts in other countries, notably Germany and Italy, has proved to be best adapted to aerial navigation, and it is said that future additions to the French aerial navy will be patterned after this type. Its predecessor, the Clement-Bayard I, Fig. 13, made thirty voyages, some of them of considerable distances, without suffering any damage, but a study of its shortcomings led to their elimination in the following model. The difference between the two may be realized by comparing the illustrations in connection with the following comments on the changes made and the reasons therefor.

The pisciform shape of the first Clement-Bayard has been retained, but it has been given more taper and more grace, the dimensions being 248.6 feet overall by 42.9 greatest diameter, this being but a short distance back of the bow. This gives it a ratio of length to diameter of 5.76. The gas balloonet stabilizers have been eliminated altogether, as will be apparent at first glance at Fig. 12. The total gas capacity is approximately 80,000 cubic feet. Like all French dirigibles it is of the true flexible type, the only rigid construction being that of the framework of the car itself. To the latter are attached all rudders and stabilizing devices, instead of making them a part of the envelope as formerly. The latter is made of continental rubber cloth.

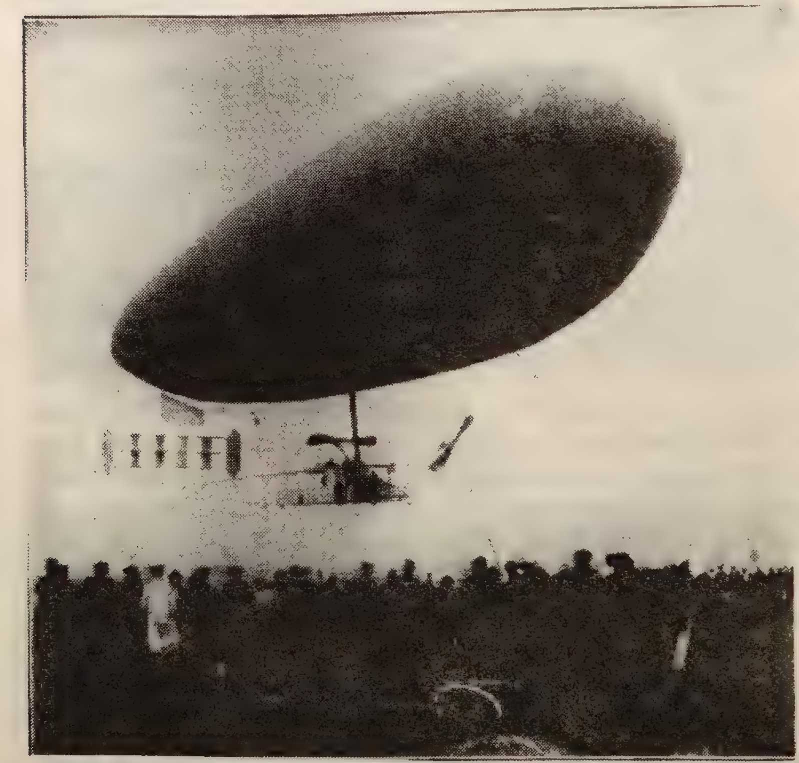

Fig. 12. Clement-Bayard II, French Dirigible

Light steel and aluminum tubing are employed in the construction of the frame supplemented by numerous piano-wire stays. This frame extends almost the entire length of the envelope, and carries at its rear end a cellular, or box-kite type of stabilizing rudder, instead of the former gas balloonets employed on the Clement-Bayard I, Fig. 13. This cellular rudder is in two parts, consisting of two units of four cells each, the two groups being joined at the top, with a space between them. In addition to acting as a stabilizer, this is also the direction rudder, its leverage being increased by making the end planes somewhat larger than the partitions of the cells. Between the cellular stabilizing rudder and the envelope is placed the horizontal rudder for ascending or descending. In the illustration this appears to be a flag, but it is in reality a long rectangular plane, which may be tilted on its longitudinal axis, the latter being at right angles to that of the balloon. There are two air balloonets of about one-third the total capacity of the balloon itself, and they are designed to be inflated by large aluminum centrifugal blowers driven from the main engines themselves.

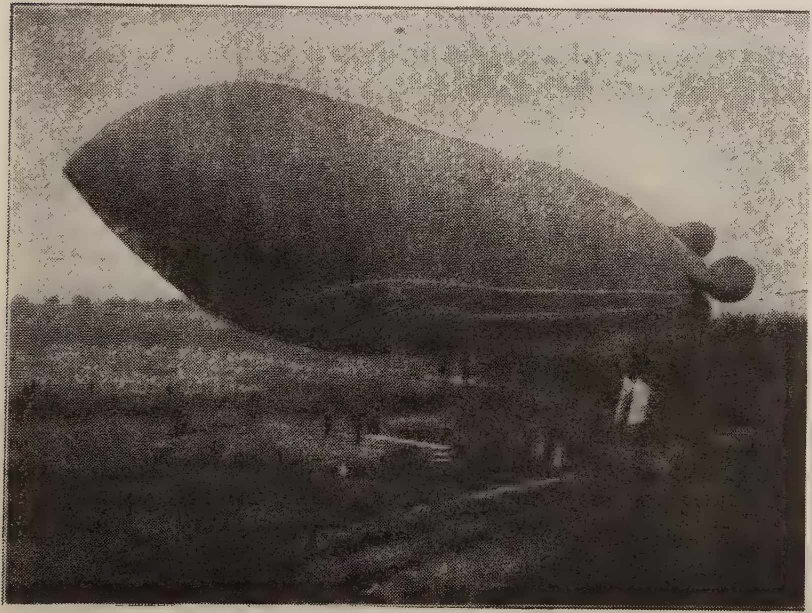

Fig. 13. Clement-Bayard I

There are two motors, each of 125 horse-power, both being of the same conventional design, *i.e.*, four cylinder, four cycle, vertical, water cooled. In fact, they are merely light automobile motors. The cylinders have separate copper water jackets and the motors themselves are muffled, which is a departure from the usual custom. Each drives a separate propeller carried on top of the main frame through bevel gearing.

The Clement-Bayard II made itself famous by its rapid and successful flight from the suburbs of Paris across the Channel to London, in October, 1910. This quick descent of one of the representatives of the French "fourth military arm" over the erstwhile sacred dividing line—the Channel—stirred the British mind, ever on the lookout for possibilities of foreign invasion, to an almost frenzied activity in aeronautical affairs. England at once entered the field and built one of the largest dirigibles ever constructed, "The Mayfly," a huge airship of the Zeppelin rigid type, which answered the query implied by its name, by not flying at all, as it was wrecked the first time an attempt was made to take it out of the shed, as mentioned farther along.

LATER FRENCH TYPES

Zodiac, Le Temps, Astratorres. After the disaster to La Republique in 1909, so little activity was shown in this field by France that the land which had given birth to the dirigible balloon seemed ready to discard what had been a source of considerable pride before it was equaled and then surpassed by Germany. From that time until the middle of 1911, only three very small units were added to the depleted French fleet, the Zodiac, Le Temps and Astratorres, and while these were very efficient for their size and were much used for training purposes, they made a sorry showing compared to what France had been doing previously. But while there was an apparent lack of interest in this branch, a general reorganization was actually being planned to build a new fleet of French military dirigibles capable of making altitudes of 6,000 to 7,000 feet, where they would be immune from any attack save that of aeroplanes which could be fought off. The scale on which this reorganization is planned is apparent in the amount of equipment used. To the only two airship sheds or "harbors" exceeding 400 feet in length previously to be found in the entire country, no less than nine have been added. All of these are 400 feet long and are so built as to be readily enlarged to 600 feet. Each of these is designed to accommodate two of the big dirigibles at once. There are no less than six large hydrogen generating plants in France, one of them having a capacity of 360,000 cubic feet per day, and others of similar size are to be added. The plans also include the building of a large fleet of big airships.

Lieutenant Selle de Beauchamp. The first squadron of the new fleet consists of four vessels, the Lieutenant Selle de Beauchamp, Capitaine Marechal, Adjutant Vincenot, and the Adjutant Reau, all of them having been named after the officers who perished in the La Republique disaster. Their type is a clever development of the old Lebaudy and the Ville de Paris, of the classic La France type, the Adjutant Reau and its sister ship being pátterned after the Ville de Paris, while the other two are improved Lebaudys. With about 250,000 cubic feet displacement, a length of 270 feet, beam 38 feet and a power-plant consisting of two 80-horse-power motors on each, these are the smallest of the four, but the most interesting, as the Lebaudy type with its single short car does not lend itself so readily to enlargement from the engineering point of view.

The outlines are strictly of the Lebaudy type, but in the Lieutenant Selle de Beauchamp essential differences are to be seen in the suppression of the vertical stabilizing fin at the extreme stern, this being replaced by fixed surfaces forming part of the vertical rudders. All rudder surfaces are doubled, this feature making possible a saving of weight and representing standard practice on all large airships of recent construction. Part of the horizontal rudder planes are nearly amidships, where they act less as rudders than as true aeroplanes lifting or depressing the ship to an even keel. There are two large air balloonets, each of which is designed to be filled by a centrifugal blower of large capacity. These blowers are mounted directly below the balloon and each one of them is driven from a different motor through a vertical rope transmission. Either of these blowers may be employed to inflate either or both of the air balloonets, so that their duplication and coupling to different motors is a measure of precaution solely. The car is supported on a deep-trussed frame of steel tubing suspended some distance below the balloon, the propellers being mounted on tubular steel outriggers, while there is a perfect maze of suspension ropes and trussing guys in sharp contrast with the simplicity of the German dirigibles of either the rigid or semi-rigid types. This should not only prove a source of greatly increased head resistance, but likewise one of weakness and danger from which an airship designed for military purposes should be free. A year or two ago, the big Zeppelin rigid airships could not rise high enough to be considered a source of danger from a military point of view, but now that this type can ascend to a height of 6,500 feet and has an effective radius of action of over 600 miles, together with a nice regulation of ascent and descent, it appears that the German airships should be much more effective.

GERMAN DIRIGIBLES

Zeppelin Airships. At the same time that Santos-Dumont was carrying on his hazardous experiments, the problem was being attacked along slightly different lines by a retired German military officer, Graf von Zeppelin, or Count Zeppelin, as he is usually called.

When a mere boy he was constantly experimenting with air craft, and succeeded in making small flights, at one time falling 50 feet. He was indomitable in his purpose to invent a successful airship, and fought for his plans against the disbelief of all those around him.

It was not until he retired from the German army, that the Count gave up all his time to the construction of an airship. He received some aid from the German government, but most of the fortune put into his giant aerial craft was his own. In fact, he spent practically everything he had. Although he, like Santos-Dumont, employed a machine of the lighter-than-air type, the construction of the gas bag was radically different.

It will be remembered that Dumont experienced much trouble on account of the envelope of his balloon being too plastic, causing it to crumple in the middle and to become distorted in shape from the pressure of the air. His efforts to overcome this by employment of air bags did not meet with great success, even in his later types.

Construction. Zeppelin employed a very rigid construction. His first balloon, which was built in 1898, was the largest which had ever been made. It is illustrated in Fig. 14, which shows his first design slightly improved. It was about 40 feet in diameter and 420 feet long—an air craft as large as many an ocean vessel. The envelope consisted of two distinct bags, an outer and an inner one, with an air space between. The air space between the inner and outer envelopes acted as a heat insulator and prevented the gas within from being affected by rapid changes of temperature. The inner bag contained the gas, and the outer one served as a protective covering. In the construction of this outer bag lies the novelty of Zeppelin's design. A rigid framework of strongly-braced aluminum rings was provided and this was covered with linen and silk which had been specially treated to prevent leakage of gas. The inner envelope consisted of seventeen gas-tight compartments which could be filled or emptied separately. In the event of the puncture of one of them, the balloon would remain afloat. An aluminum keel was provided to further increase the rigidity. A sliding weight could be moved backward or forward along the keel and cause the nose of the airship to point upward or downward as desired. This would make the craft move upward or downward without throwing out ballast or losing gas. Under each end of the balloon a light aluminum car was rigidly fastened, and in each was a 16-horse-power Daimler gasoline engine. The two engines could be worked either independently of each other or together. Each engine drove a vertical and horizontal propeller. The propellers each had four aluminum blades. As will be seen from Fig. 14, the cars were too far apart for ordinary means of communication and so speaking tubes, electric bells, and an electric telegraph system were installed.

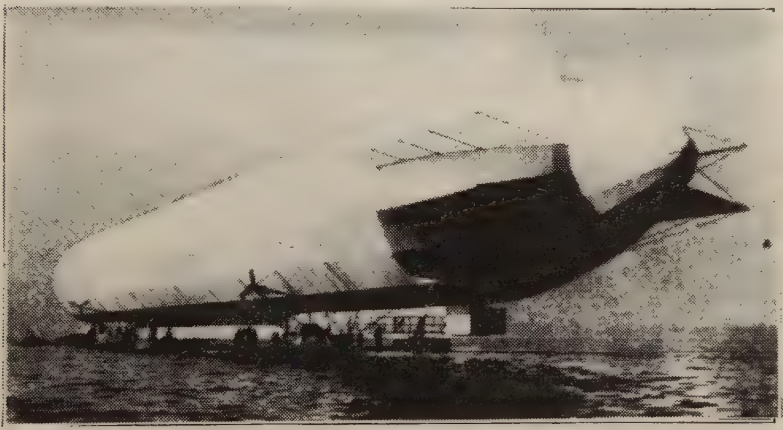
Fig. 14. Zeppelin Dirigible Rising from Lake Constance

First Trials. Very little was known as to the effects of alighting on the ground with such a rigid affair as this vessel, therefore the cars were made like boats so that the airship could alight and float on the water. The first trials were made over Lake Constance in July, 1900. The mammoth craft was housed in a huge floating shed, and the vessel emerged from it with the gas bag floating above and the two cars touching the water. She rose easily from the water, and then began a series of mishaps such as usually fall to the lot of experimenters. The upper cross stay proved too weak for the long body of the balloon, and bent upward about 10 inches during the flight. This prevented the propeller shafts from working properly. Then the winch which worked the sliding weight was broken and, finally, the steering ropes to the rudders became entangled. In spite of all this, a speed of 13 feet per second, or about 9 miles per hour, was obtained. These breakages made it necessary to descend to the lake for repairs and in alighting the framework was further damaged by running into a pile in the lake. The airship was repaired and another flight was made later in the year, during which a speed of 30 feet per second, or 20 miles per hour, was obtained.

Second Airship. Zeppelin had sunk his own private fortune and that of his supporters in his first venture, and it was not till five years later that he succeeded in raising enough money to construct a second airship. No radical changes in construction were made in the new model, but there were slight improvements made in all its details. The balloon was about 8 feet shorter than the original and the propellers were enlarged. Three vertical rudders were placed in front and three behind the balloon, and below the end of the craft horizontal rudders were installed to assist in steering upward or downward. The steering was taken care of from the front car.

The most important change was made possible by the improvement in gasoline engines during the preceding five years. Where, in the earlier model, he had two 16-horse-power engines, he now used an 85-horse-power engine in each car, with practically the same weight. In fact, the total weight of the vessel was only 9 tons, while his first airship weighed 10 tons.

His new craft made many successful flights. One was made at the rate of 38 miles per hour, and continued for seven hours, covering a total distance of 266 miles. During the course of the flight, Zeppelin made a landing to take on board a representative of the German ministry of war. In one trial flight with both motors in operation, the airship easily outdistanced the steamers on the lake. The German War Department finally took over the aeronaut's ship and plant, and the government appropriated $535,000 to help carry on the experiments. Since then Zeppelin has built several airships, all of the same type, and others are now under way of construction.

They embody no remarkable changes in design, the principal alteration being in size. The latter type is illustrated in Fig. 15. In one, the gas bag was increased to 446 feet in length and it held over 460,000 cubic feet of gas. This gave it a total lifting power of 16 tons. With this, Zeppelin made a voyage of over 375 miles. He was in the air for twenty hours on this trip and carried eleven passengers with him. In August, 1908, the Zeppelin left its great iron house at Friedrichshafen and sailed in a great circle over Lake Constance. This was to be the nucleus of the aerial navy and Germany considered herself the monarch of the air, as Great Britain was the monarch of the sea.

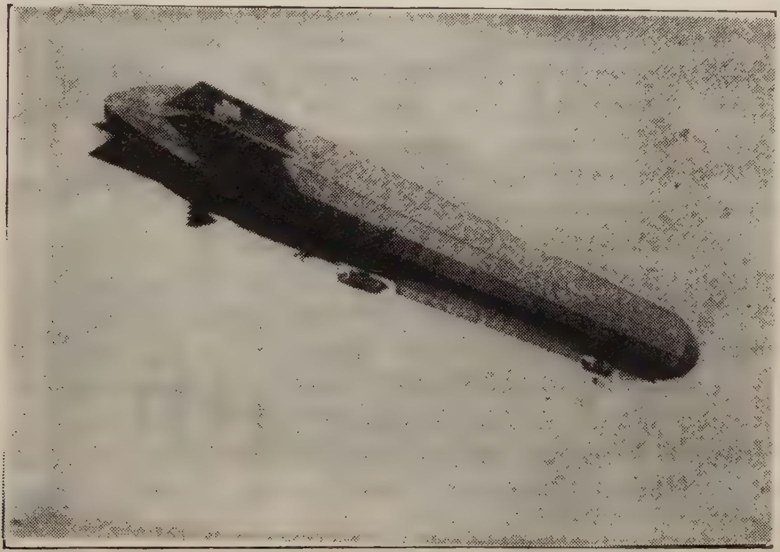

Fig. 15. A Zeppelin Airship in Flight

The next day, however, the ship was destroyed at Echterdingen in a storm. The German people at once came to Zeppelin's aid, The government led a subscription list with $125,000. In all $500,000 was raised, and the Count again started work on a new aerial craft which was taken over by the government and christened Zeppelin I. On March 19, 1909, the Zeppelin I ascended with twenty-six passengers and maneuvered under perfect control for an hour and a half in a series of government tests.

Longest Airship Flight. Still another ship, the Zeppelin II, had been constructed, without the public knowing anything of its completion, inflation, or of the preliminary tests. It suddenly appeared before the world in a continuous flight of 900 miles. Count Zeppelin had not allowed a word to be made public relative to his intention of undertaking an endurance trip. It was, however, commonly believed that he intended to seize the first favorable opportunity to proceed to Berlin. On May 31, 1909, the Count in his newest aeronat descended at Göttingen at noon after a flight of thirty-six hours, during which he had covered 850 miles, thus more than doubling the best previous record in aviation for both time and distance.

The vessel had quietly left the floating shed on Lake Constance a little after nine o'clock at night, with Count Zeppelin himself, two engineers, and a crew of seven men on board. Starting from Friedrichshafen in a direct line towards Berlin, the great ship continued until it reached the frontier of Saxony, where it was headed straight for Leipsic. On it went, crossing Halle, into the very heart of Germany, as far as the great air harbor at Bitterfeld, where the Parseval airships were stationed in the large plant belonging to the Society for the Study of Motor Aeronautics. Lack of knowledge that such a thing as an air harbor existed in Bitterfeld led the press of the world to make the error that the ship had failed to reach her destination, which, it was assumed, must be Berlin, since the ship was headed in that direction. The airship after describing a great circle at Bitterfeld, turned again and sailed south.

Meantime the military authorities at Berlin were without advices as to the Count's plans, but they learned from private dispatches that the airship was approaching. An enormous crowd waited in vain for five hours in Berlin in the expectation of seeing Count Zeppelin arrive in his airship. The Kaiser came all the way from Potsdam, waiting on the moonlit field until ten o'clock, before word was received from Count Zeppelin that he had turned back.

The whole night long the flight toward Friedrichshafen was continued. In the morning it was found that a descent would have to be made to replenish the supply of gasoline. It was decided to cast anchor in a quiet valley which was protected by a steep hill just ahead of them. In the descent, the airship's bow prevented the man at the helm from seeing straight ahead, and, while the craft was closely skimming this hill, a pear tree suddenly shot up in its course. For the first time there happened in the air what so often happens on the water—the ship was steered right into the obstacle. From the ground it seemed for a moment as though the craft were doomed to certain destruction, as it appeared to be swooping straight into the trunk. When the big ship hung for a second and then forced its way through and circled slowly around a cheer went up from the relieved watchers underneath. It was found that the bow was crushed and the forward frame torn away.

In preparing for the trip to Friedrichshafen from the scene of the accident, all the damaged portion was cut away in front of the forward car, and the motor and propellers removed. The pointed bow of the ship was thus changed to a flat disk shape, but was so covered with cloth as to give a slight suggestion of pointed shape. A man was stationed in the passageway between the cars to act as a moving weight, thus assisting the rear planes to maintain the balance, as the forward planes had been destroyed. The speed was necessarily slow, and owing to the greatly diminished carrying power, the ship stopped for fuel while under way. Friedrichshafen ultimately was reached in safety.

The airship in which Count Zeppelin accomplished this flight was 448 feet long and had a diameter of 42 feet. It was equipped with two motors which furnished 220 horse-power. Besides being the largest dirigible in the world, its claim for carrying capacity is as yet uncontested.

On June 29, 1909, Zeppelin I, under command of Major Sperling, started from Friedrichshafen to go to its future home port at Metz. A breakdown in the engine room enforced a landing on the plains not far from Lake Constance. While the ship was waiting for duplicate parts of machinery a heavy gale arose, which prevented the continuation of the voyage even after repairs were completed. For nearly a week the storm-bound vessel was exposed to the violence of the elements, under the open sky, without damage to the craft. Flight was resumed on the night of July 3, and Metz was safely reached on the morning of July 4. The Zeppelin III, larger and more powerful than its predecessors, was then being built. On August 27, it made a successful flight from Friedrichshafen to Berlin.

Deutschland I and II. In honor of the governmental assistance that made their building possible, the later Zeppelin aircraft were named in honor of the Fatherland. The first of these was the largest airship that had been built up to that time (1910), but like her predecessors she was found to be more or less cranky, to apply a marine term by analogy. In other words the maneuvering ability of the craft was defective. Also like her predecessors, her existence was an extremely short one. Due to the motors failing at a critical moment, which coincided with a lack of buoyancy, the airship could not be kept afloat and as luck would have it, this occurred over a pine forest into which the huge hulk sank, the envelope being impaled at numerous points on the tops of the trees and the car and fittings being badly wrecked.

To provide greater lifting power for just such emergencies, the hull of the Deutschland II was made lighter, permitting the transportation of a greater amount of ballast for the same number of passengers. In other respects, the new airship was scarcely more than a copy of her predecessor and with no greater speed or any better maneuvering qualities. To further provide against accidents of a similar nature, special tests were made over Lake Constance to familiarize the crew with the exact amount of lifting and depressing power obtainable from the propellers and rudders alone. It was found that with only two motors and two propellers in action, the new ship could be raised by power like an aeroplane, from a static level of equilibrium at an elevation of 2,132 feet to 4,756 feet. This represents a purely dynamic lift of more than two tons (4,400 pounds). With three motors and four propellers the ship rose to 5,904 feet, adding nearly another ton of dynamic lift (1,980 pounds). It remained for some time at this level, carrying four passengers, the regular crew of nine, 242 pounds of fuel and oil, and 4,400 pounds of ballast. If one-half of this ballast had been thrown overboard, an elevation of 7,544 feet could have been reached, while still retaining more than a ton of ballast in reserve. This shows an astonishing reserve of floating power for the arrow-like type of Zeppelin balloons under favorable conditions, *i.e.*, with the motors intact and when not overloaded with passengers, and it would add greatly to their value for military purposes. At such heights they would be immune from artillery fire. Despite their huge bulk, their diameter does not exceed the spread of wing of a Wright biplane, which at the same height is an almost invisible speck, while a Zeppelin at the same altitude looks like a match, its lean shape making it a poor target. In the thin air, its speed is increased, so that with a favoring wind, even the slow Deutschland could make 60 miles an hour.

Although the new Deutschland was thus amply insured against conditions such as caused the wreck of its predecessor, it shortly fell a victim to an odd and unforeseen accident—collision with the shed. It hardly seems proper to term such a mishap either odd or unforeseen when it is recalled that a majority of the huge airships of recent build have all come to grief in a somewhat similar manner, *i.e.*, in being taken out of or returned to the shed, the breaking in half of the biggest of them all, the British naval dirigible, being a noteworthy case in point. As in the case of the latter, the Deutschland also "broke in two." Mishaps from apparently trivial causes, resulting from lack of experience in handling such huge craft, involve great losses of money and prestige when they happen to a large and costly dirigible, whereas they are almost negligible in the case of the aeroplane.

Schwaben. Taking advantage of the experience gained in the building of the two Deutschlands, Zeppelin set about building another and this—the Schwaben—was almost half completed at the time the second Deutschland was wrecked. The new airship was specially designed for passenger carrying and its dimensions marked a decrease in the huge proportions that characterized its predecessors. The dimensions of the last Deutschland were 499 feet length overall, diameter 46 feet, and with 18 independent gas compartments, giving a displacement of 667,560 cubic feet; whereas the displacement of the Schwaben is 634,500 cubic feet, on a length of 462 feet, the beam being 46 feet. The envelope is divided into only 17 gas compartments or cells. Numerous experiments were made to improve the shape of the hull, as the result of which the conical bow of the Deutschland was replaced by an ovoid shape in the Schwaben. To diminish friction the outer envelope of the new ship was stretched over the frame with extreme care so that it is so smooth and firm that non-technical observers have compared the "solid hull" of the Schwaben (swallow) to a man-of-war, owing to the gray color. To further cut down head resistance, the time-honored aeroplane rudders, fore and aft, were abandoned—quite a radical step as they had always proved efficient. In their place, a single set was attached to a more graceful single rudder frame at the extreme rear, where they are combined with vertical rudders and cleverly supported by stabilizing fins. It was found that by this means, skin friction and head resistance were cut down, steadiness improved and the efficiency of all the rudders wonderfully increased, so that the big ship could make a complete turn in a circle of only 800 feet radius. What was even more surprising was the fact that the lifting power did not suffer by the removal of these lifting planes, the kite effect of the smooth cylindrical hull compensating for their absence to an extent that substantially increased the floating power of the Schwaben as compared with Deutschland II, owing to the greater speed of the former. The lack of efficiency of an aeroplane surface with a very small aspect ratio, or very long in its line of longitudinal movement, as must be the case when attached to a big envelope, is offset in a dirigible by the small weight it has to bear dynamically per square foot of its immense area. As the result of long-continued experiments in the Zeppelin laboratory, the Schwaben was fitted with two- and four-bladed propellers of greatly increased efficiency, while the head resistance of their supporting brackets was greatly reduced by covering them with cloth in the form of useful stabilizing fins. The result of these improvements was apparent in the greatly increased speed, the Schwaben making a fraction under 43 miles per hour in calm air in the course of numerous trial trips carried out over a measured stretch of railway line, in both directions. As this rate of travel is equal to that of many of the large biplanes which have only an effective speed of 40 miles per hour, it revolutionizes all former ideas regarding the inferiority of the dirigible in this respect as compared with the aeroplane. With only three of the four motors running, all previous dirigible records were broken by making 38 miles per hour. In a race from Darmstadt to Frankfort, the Schwaben proved an easy victor over a

Euler biplane. This great improvement in speed has been due not alone to a decrease in the head resistance, but likewise to the increased efficiency of the motors, as after long experimenting with automobile types, Zeppelin abandoned them and built special engines in his own plant for the Schwaben. Six-cylinder motors are employed instead of the fours previously employed, and their output increased from 110 to 165 horse-power, so that the total driving power of the new ship is 660 horse-power. Their reliability was also greatly improved, so that in over a hundred passenger trips, of which some were 700 miles long, the Schwaben's engines have never given any trouble. The success of the numerous passenger trips was not only due to the increased power but also to the perfected methods adopted of handling the big ship at landings. Mechanical docking devices have been provided by which the ship is securely held until safe in the open air, before an attempt is made to take it into the shed. A rail on each side of the shed runs far out into the open through each of the doors at both ends. Each length of rail is made of two narrow channel plates riveted together back to back. Two sets of rollers run on each rail, each set bearing against the under side of the upper flanges. Four steel cables made fast to the airship's frame are attached to the four sets of rollers, or trolleys, and all may be slipped simultaneously. The two rails are so far apart that a dirigible lashed to them can not be swayed if it have sufficient lift, this being obtained by the removal of the passengers and ballast before pushing the ship into the shed, and not taking them aboard again until the big craft is safely out of the latter again before starting a flight, which begins by the simultaneous release of all the hawsers. But entering the shed with a brisk wind blowing at right angles to its axis and to the rails is still a difficult feat. In this case, the ship is halted in the open over the track, heading into the wind. One of the front cables is fastened to the rollers nearer the shed on the windward rail. With this set of rollers as a fulcrum, the ship is worked around by pulling at the rear end, steadying it along the sides, and simultaneously pulling the lee side down, until it becomes parallel with the rails. It is then a simple matter to fasten the remaining cables, unship passengers and ballast, and roll the craft into its house. Even with these improvements, the device is still primitive and depends upon the employment of a large number of men skilled in handling the big aircraft. Damage from accidents of this nature has also been further provided against by strengthening the structure of the ship itself, the cars and cabin being built of corrugated aluminum, while the strength of the pneumatic buffers under them has also been increased. Of equal importance to the improved methods of docking are the provisions for safely anchoring the huge dirigible in the open. A safe anchorage over unobstructed grounds, mostly parade grounds, has now been provided in most German cities.

The holding device is a development of the method by which in the past severe squalls have occasionally been weathered. It differs from the latter in that the pivotal point around which the ship swings into the wind's direction is now placed on the frame of the ship itself, instead of on the ground. Even with the short single bow cable formerly used successfully, jerks which strained the frame and the cable were not entirely avoided in gusty winds, too much play in the bow having snapped the long cable and freed the ship on one occasion, though it did not damage the frame. In place of the single cable there are now four, giving greater safety. They are fastened to a ring that swivels round a strong pin in the reinforced framework and are permanently carried by the ship. When anchoring, their free ends are made fast to four heavy cubes of concrete embedded in the ground, and so placed that the four cables evenly radiate toward them from the pivot on the bow. Due to its rigidity, the ship turns freely around the apex of this pyramid of cables as smoothly as a new weather vane. Unshipping ballast at the bow makes this pyramid very rigid.

Plans have been completed for the inauguration of an American dirigible passenger service similar to that in operation between the cities of Berlin and Frankfort during the past two years. Airships similar to the Schwaben will be employed, the route being between Philadelphia, Atlantic City, and New York, the stopping place in the first-named city, which will be the headquarters, being erected on the roof of the Bellevue-Stratford hotel. This landing platform will be 190 feet long by 62 feet wide and at an elevation of 300 feet above the ground. It is to be finished with a surface of sod and clay similar to a baseball diamond. One round trip per day will be made, the fare being the same as in Germany, that is, $50.

Parseval. Germany has adopted another type of airship, that of Major von Parseval. His construction is very different from that of his compatriot, Zeppelin. Instead of the rigid construction of the latter, the Parseval has no rigid connections except between the car and the propeller. Two air balloonets are employed, one inside each end of the balloon, the pumps being so arranged that either one can be filled or emptied independent of the other, allowing the balloon to tilt upward or downward as desired by the pilot. In addition, the car itself is on two rollers and can be moved forward or backward on two cables, thus placing the weight so as to cause the balloon to tilt. The surfaces which steer the balloon are blown under pressure. The propeller has four blades, and is driven by a 90-horse-power gasoline engine.

The Parseval's peculiarity lies in its propeller. Instead of the solid blades common to other airships, there are four strips of canvas with weights at the end, held rigid by centrifugal force when in motion, and hanging limp when the ship is at rest.

The Parseval II was of almost the same construction, and had a promising though short career. It collapsed ignominiously on the roof of a villa after a flight of over eleven hours. A new Parseval II has been constructed, and stationed at the new government air harbor at Bitterfeld. It has two motors with a total horse-power of 240.

Parseval Sporting Type. The Parseval flexible system having proven such a success, the makers (Die Motor-Luftschiff-Studiengesellschaft, Berlin) have brought out the Parseval V. The original intention was to design a dirigible of the smallest dimensions compatible with the system, and while, according to theory, it would have been possible to reduce the dimensions considerably more than has been the case, the miniature thus obtained would have been a mere toy, devoid of any practical value. The new Parseval, accordingly, has been built to carry three persons and a sufficient amount of ballast for a six- to seven-hour run at a speed of not less than 20 miles per hour. The Parseval V thus constitutes the smallest of its class and is mainly intended for the use of private parties and aeronautic clubs. Its dimensions are 129 feet overall, maximum diameter 25.3 feet, and its displacement 42,000 cubic feet. The envelope is made of lined balloon fabric of a minimum strength of 730 pounds

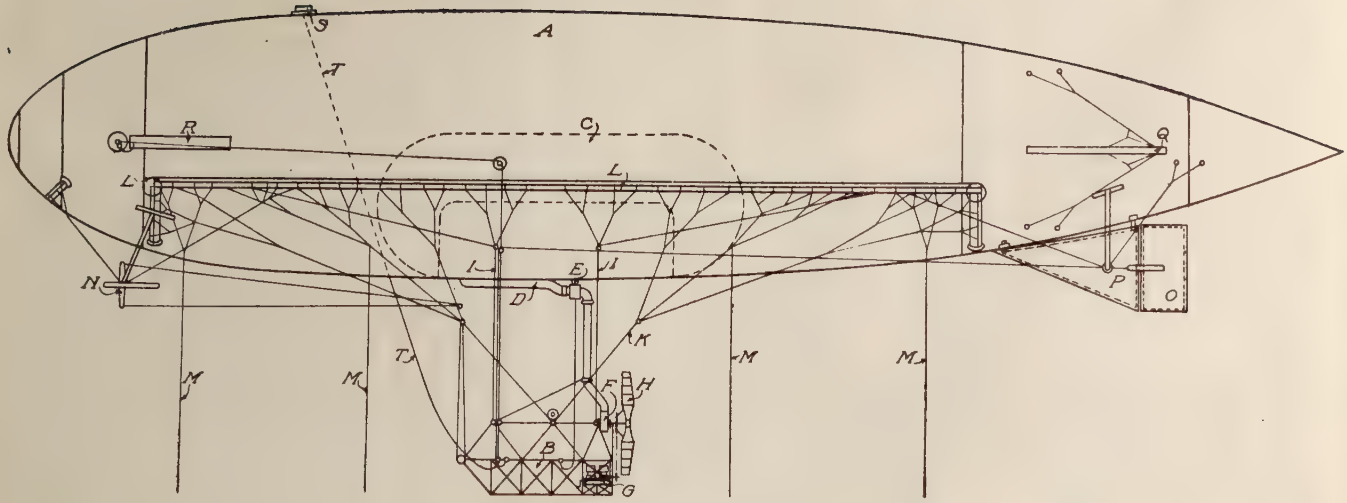

Fig. 16. The Parseval V

A, Balloon body; *B*, Car; *C*, Ballonet; *D*, Conduit connecting ballonet to air pump; *E*, Ballonet valve; *F*, Air pump; *G*, Motor; *H*, Propeller; *I*, Parallelogram ropes; *K*, Sliding ropes; *L*, Belt; *M*, Lifting rope; *N*, Elevation rudder; *O*, Side rudder; *P*, Vertical stabilizing surface; *Q*, Horizontal stabilizing surface; *R*, Emergency valve for rapid discharge; *S*, Gas valve; *T*, Valve rope.

per foot, and weighing one ounce per square foot. The balloon is made up of a number of longitudinal sections, a construction which somewhat reduces the fractional resistance of the surface. The details of the construction are illustrated in Fig. 16. It shows the characteristic Parseval shape, rounded off elliptically in front and tapering to a slender point in the rear, in other words, the pisciform outline recommended by Renard. A distinctive feature wherein it differs from all others of the same make is that the vertical steering is effected by a horizontal rudder located at the head of the balloon and operated by cables from the car, instead of the usual balloonets. This has worked so well in practice that the little airship is capable of maneuvering within a few yards of the ground without danger. A single centrally-placed air balloonet fed by a centrifugal air pump is provided to take care of expansion and contraction, as well as gas losses. To prevent excessive stress being placed on the envelope a safety valve is provided in the flexible pipe connecting the pump and the air balloonet. This valve opens automatically when subjected to a pressure equivalent to 0.6 inch of water, allowing sufficient air to escape from the balloonet to maintain the normal pressure.

The gas valve which is located at the summit of the balloon is also designed to operate as a safety valve, but as it does not operate of its own accord until a pressure in excess of one inch of water is reached, no gas losses occur unless the expansion of the gas has forced all the air out of the balloonet. Both of these valves may also be operated by cables leading to the control board. The usual "ripping valve" is also provided in the form of a narrow strip of balloon fabric glued over a long cut in the envelope. This can be ripped open in cases of emergency at a moment's notice. The stabilizing surfaces are of triangular outline and are combined with the direction rudder at the rear. They consist of frames of steel tubing autogenously welded together and tautly covered with light balloon fabric, provided on both sides with vent holes into which air is forced by the movement of the airship when in flight, thus keeping the fabric tight and smooth. Side and front elevations of the car are shown in Figs. 17 and 18. It is built of steel tubing and measures 14.75 feet in length by 3.25 feet high, being 2.79 and 2.13 feet wide at the top and bottom, respectively. Though the normal carrying capacity is three, including the pilot, there is sufficient accommodation for four, but as all the controls are centered at the pilot's stand forward, the airship can readily be handled by one man. The power plant is compactly arranged at the rear of the car. The engine is a four-cylinder, 25-horse-power Daimler motor, running at 1,200 r. p. m. and using but 0.54 pint of gasoline per horse-power at full load. The flywheel acts both as a fan and a belt pulley for driving the pumps, and the radiator is placed directly behind it, the main driving shaft passing through the radiator and being supported by an outboard bearing back of it. The propeller is placed upon a bracket above the motor and is driven by a silent chain, the two sprockets having a ratio of 4 to 1. The propeller is of the 3-bladed type with a diameter of 9 feet 9 inches and differs from those of the earlier Parseval airships in that the blades are semi-rigid, being constructed on a framework so pivoted at the base of the blade as to prevent the stresses upon the latter reaching a point dangerous to their safety. The suspension of the car

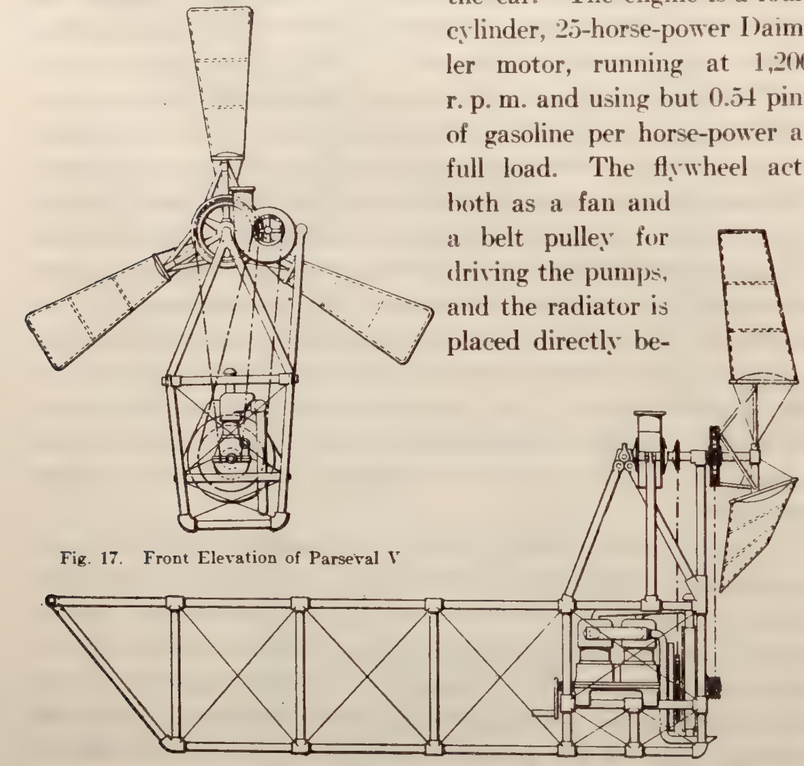

Fig. 17. Front Elevation of Parseval V

Fig. 18. Side Elevation of Parseval V Showing Motor and Transmission Gear

is analogous to that of the larger Parseval types, except where slight alterations were necessary owing to the reduced dimensions, the car depending from the balloon by cables arranged in parallelogram form so as to always keep it hanging in a direction parallel to the longitudinal axis of the balloon. But it is otherwise free to travel back and forth in a path controlled by two idlers on sliding ropes running obliquely fore and aft. This arrangement prevents any accidental inclination of the balloon in starting due to the thrust of the propeller, which accordingly always acts with its driving point located at the center of resistance of the airship.

Gross. The Gross has also been approved by the German government. This is a dirigible of the usual type driven by two 75-horse-power motors.

The Gross II has been recently built for the Prussian Aeronautical Battalion under the supervision of its commander, Major Gross. It is almost identical with the Gross I. Its movements are kept more or less secret, but it frequently crosses over Berlin. Two hangars or air harbors have been constructed for the Gross I and her sister ship.

Krell I. That it is possible to build a successful airship of the imposing dimensions of the various Zeppelin craft without the characteristic rigid frame deemed indispensable by the latter, is shown by the test of the Krell I, which was finally launched in the fall of 1911, after two years had been spent in its construction. All the weight saved by the elimination of the rigid frame has been put into additional propelling power, and as the new airship has almost as low a head resistance due to its rigging as the Zeppelin, and a total of 500 horse-power, as compared with the 165 horse-power of the first of the latter type, its speed is much greater. The Krell I may best be described as a "non-rigid Zeppelin." Its large size—393.7 feet long by 42.65 feet diameter with a displacement of 473,739 cubic feet—makes necessary a slender-shaped balloon, similar to that of the Lebaudy non-rigid dirigible, the Morning Post, previously described, because even the natural static pressure of the gas against the back of the envelope when under way, due to the greater "head" of gas resulting from increased beam, acts as a stiffener. This clearly illustrates how much of its strength the big Zeppelin derives from the pressure of the gas alone, quite independent of the rigidity of its frame. There is the same long passageway of triangular cross section running the entire length of the ship directly below the balloon, but in this case, it is made of cloth without any stanchions, the only rigid part of it being the flooring, though it is said to feel no less solid than the Zeppelin construction. This not only provides communication between the three cars, but also houses the water ballast tanks as well as the fuel and oil tanks, thus distributing the load over the entire length. The three cars differ from those used on the Deutschland in that the pilot's bridge has been placed in the center car, instead of the forward one, thus permitting two motors to be placed in the latter and the other two motors in the after car. The passengers are carried in the center car. However, the propellers being directly mounted on the cars and not on the flexible hull, thus avoiding long transmissions, more propellers have been provided. There are three on each car, or six in all. In each of the forward and after cars, a 125-horse-power motor drives two 2-bladed propellers, mounted on outriggers at the sides, while the other motor of the same power drives a single 4-bladed propeller mounted directly on the elongated shaft of the motor extending behind each car. These shafts are supported by steel tubing in pyramid form. The two engine cars are so far apart that no interference results from this compact arrangement, especially as the center is raised to the same level as the other two, following Zeppelin practice in this respect. The auxiliary power plant is carried in the center car, and as the blowers for maintaining the necessary pressure in the air balloonets must naturally be large on an airship of such size, this takes the form of two 25-horse-power motors. Only one is employed, the other being held in reserve. The three cars are only slightly lower beneath the hull than were those of the Deutschland, the short suspension cables being made fast to the cloth sides of the long passageway. But several auxiliary cables are also led from the cars directly to the envelope to which they are attached, as in the Parseval type, by layers of bands or huge reinforcing "patches" sewed to the outside of the balloon. Horizontal rudders, similar to those of the Zeppelin, are employed, but they are much smaller and are mounted on the sides of the passageway instead of directly on the balloon. They are placed above the front and rear cars and there is also a horizontal propeller, placed beneath the floor of the center car, designed to be driven by the reserve motor in case of emergency. Communication between the cars and the passageway is by means of ladders, the cars themselves being surrounded by a tubular framework resembling a cage. The huge vertical rudder is similar to that of the Clement-Bayard II. It is like a Venetian blind with five slats and is mounted just below the easy curving stern, being supported by a tubular framework secured to the envelope at points protected by reinforcing patches, in exactly the same manner as the Parseval construction of this essential. The shape of the hull is also similar to that of the Parseval, but it has been elongated to such an extent as to more closely resemble the Zeppelin.

Veeh I. In contrast with all of the German dirigibles thus far described, the Veeh embodies many of their features, but at the same time differs radically from every one of them. It is of the semi-rigid type, but is of such novel construction as not to resemble any of the airships of this type previously built. The frame is in the form of a single girder extending the entire length of the balloon, from the tip of the bow to the point of the stern. It is in the form of a keel and is built up of light steel tubing. This results in quite a novel form of airship. As the balloon is rigidly connected with the steel keel throughout its length, all forces are well distributed and the necessity of compensating for any stresses by an excessive tension of gas pressure is eliminated. The envelope is thus subjected to considerably less strain and the risk of explosion greatly reduced. The rigid girder frame also permits of a simple and compact arrangement of the power plant and drive besides affording a solid support for the stabilizing surfaces and the rudder. Two pairs of 2-bladed wood propellers, 13.2 feet in diameter, are driven by two six-cylinder, 150-horse-power motors through triple, parallel, rubber cables. The propellers are enclosed in light metal cases to protect the envelope and the passengers in case the propeller should break under the high centrifugal stresses. The lateral rudders are placed in the air current developed by the propellers, which makes them so effective that the airship may be turned practically on its own axis. Both the elevating rudders and the stabilizing surfaces are solidly supported by brackets attached to the steel keel, the tubular framework of the latter being covered with fabric and in

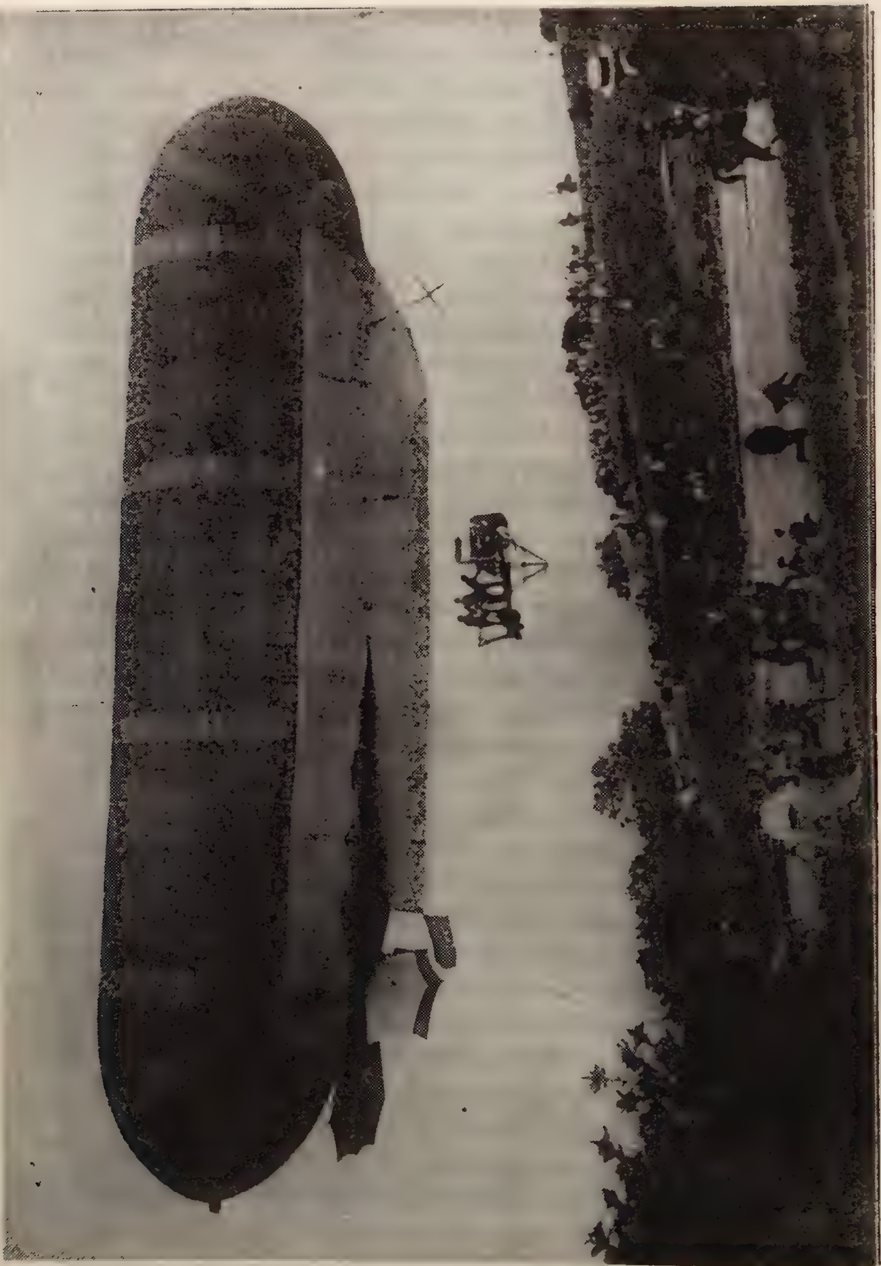

Fig. 19. Nulli Secundus. British War Dirigible

part closed up by panels of cloth, to cut down the head resistance. These panels also act as lateral stabilizing surfaces in addition to affording shelter for the passengers. The envelope is of metallized balloon fabric with a capacity of approximately 9,800 cubic yards and in the form of an elongated cylinder with comparatively blunt ends of similar shape. It is subdivided into nine independently dismountable gas compartments and is provided with two air balloonets, each of about 1,100 cubic yards capacity. The airship measures 248 feet in length and has a spacious trapezoidal gondola between the frame of the keel, measuring 132 feet long by 3.3 feet wide at the center. Inclusive of the frame, rudder, stabilizing surfaces, propellers, motors and drive, the total weight is only 3,100 pounds. With a fuel supply sufficient for a 10-hour flight and the full complement aboard, the airship still has a reserve buoyancy of 2,200 pounds. Skids and spring-mounted wheels are provided below the frame to absorb the shocks of landing. Owing to the remarkable simplicity of the design and the low cost of the materials employed, the expense for construction is comparatively small.

BRITISH DIRIGIBLES

In spite of the fact that a great deal of money has been spent upon the building of dirigibles in Great Britain during 1910 and 1911, the results have amounted to little or nothing, being confined practically to the short trips of the Nulli Secundus and the various trials and tribulations that the Morning Post has suffered almost every time an attempt has been made to fly her. The last-named airship is a large Lebaudy type constructed in France, while the former is of British design and construction, having been built for military purposes. As dirigible standards go nowadays, however, the Nulli Secundus is only a third- or fourth-rater. Fig. 19 shows the general construction excellently. It will be noted that the direction rudders are placed forward instead of at the stern, as is the usual practice. The gas bag is provided with a hull or keel, similar in form to that of a ship, and from this is suspended the car. At the forward end and on either side of the keel is a series of five horizontal projecting fins, by means of which the airship's course can be deflected up or down. At the stern and on a level with the bottom of the keel, is a transverse horizontal plane which forms an additional rudder for use in ascending and descending. The Nulli Secundus has a length of 111 feet and a capacity of 85,000 cubic feet. She is driven by two propellers run by a single motor and is capable of carrying three persons at a speed of 20 miles per hour. Instead of employing the usual balloon cloth of cotton or silk combined with rubber, the gas bag is made of eight layers of goldbeaters' skin—about as expensive a material as could well be found for the purpose. This is made from the lining of the digestive tract of cattle and about 60,000 animals were necessary to furnish sufficient for the making of this one envelope. Compared with the one insignificant dirigible of 30,000-cubic-foot capacity owned by the United States, the Nulli Secundus takes on considerable importance, but when judged according to the standards set by the Continental governments, she is a negligible factor. Two or three of this type have been built for British military use and are employed in training army officers.

A huge British dirigible for naval use, and of which much was expected, was built during the winter of 1910—1911. In its dimensions as well as in its numerous special features of design and arrangement, this monster was to surpass anything of the kind that had ever been built, and its ability in the air was to be in proportion. Unlike previous British dirigibles, the Mayfly, as the big ship was named, was built with a rigid frame similar to the Zeppelin type. There probably have been few airships built in any country that involved the expenditure of so much money as this one, but the only reward of months of labor and waiting was to see her ignominiously broken in half when an attempt was made to take her out of the shed.

AMERICAN DIRIGIBLES

United States War Balloon. At The Hague Peace Congress, the representatives of the United States signed a clause by which she, of all the first or second rate powers, was debarred from using airships as a means of offensive warfare. Yet the United States, by the purchase of the Baldwin dirigible balloon in 1908, committed herself to a policy of maintaining airships as a part of her military equipment.

The Baldwin was the only one of the three aerial craft that fulfilled the government requirements during the trials made that summer at Fort Meyer, Virginia. Specifications were sent out by the chief signal officer of the army, inviting bids for a dirigible balloon. Among the proposals received was that of Capt. Thomas Baldwin, and after the official trials the contract was awarded to him. He delivered his airship in August, 1908, and it received the name, Dirigible I. It has a length of 96 feet, a maximum diameter of 19½ feet, a volume of 20,000 cubic feet, and is designed to carry two persons. At its official trial, it made a maximum speed of nearly 20 miles an hour, and remained in the air for two hours, covering a distance of 27 miles. A general view of the United States army airship, Dirigible I, is shown in Fig. 20.

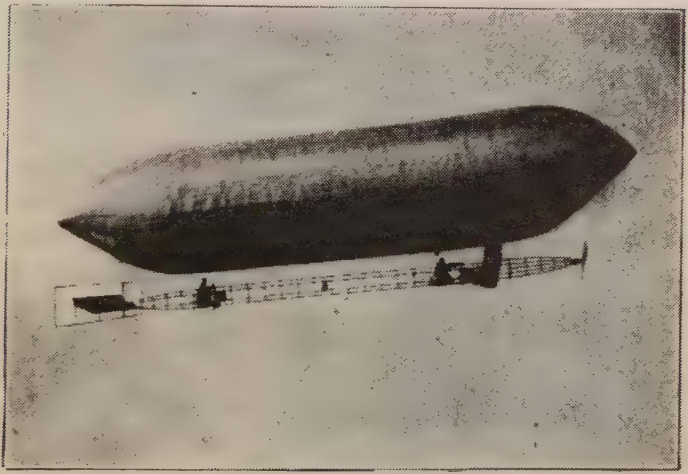

Fig. 20. Captain Baldwin's Dirigible, the United States Army Dirigible I

The America.* As Wellman's attempt to cross a stretch of 3,000 miles of ocean in a dirigible was by far the most ambitious undertaking of the kind ever attempted, a detailed description of the airship and the numerous special features designed to make such a lengthy voyage possible will be of interest. Contrary to the general impression, this was not the same dirigible in which the unsuccessful attempt to reach the North Pole from Spitzbergen was made.

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* Excerpt from Chief Engineer Vaniman's detailed description of the America.

The balloon itself measured 228 feet in length overall, and had a diameter through its greatest transverse section of 52 feet, giving it a lifting power of close to 12 tons, or to be exact, 23,650 pounds. The weight of the envelope alone exceeded 2 tons, the balloon proper being made of a costly fabric composed of two layers of silk and one layer of fine cotton cloth, gummed together with rubber. There were about 4,000 square yards of this rubberized cloth required, weighing approximately a pound to the yard, and having a tensile strength of 100 pounds to the square inch. This combination was adopted as the silk and cotton provide great strength to resist the internal and external pressure, while the rubber binder made the fabric almost gas-tight.

At the center of pressure, or the greatest diameter of the balloon, the fabric was used three-ply, and the most painstaking care was used in every detail of its construction to obtain the maximum strength and at the same time reduce the gas leakage to a minimum. The seams were wide lapped, sewed, and gummed, and extra strips were glued over them to cover the needle holes to prevent the escape of the gas. As the weight of the balloon complete with its air balloonets, valves, and other appurtenances was 4,700 pounds, it had a net lifting force of 18,950 pounds. In other words, the volume of gas required to inflate it was sufficient to carry its own weight in the air and a load of almost 9½ tons besides. Although hydrogen gas has a weight of only one-fourteenth that of air, it required more than a ton of it to inflate this huge gas bag to its full capacity. The manufacture of this quantity of gas was not an easy or inexpensive operation. The plant to generate the gas was made in Paris, shipped to Atlantic City in sections, and there set up just outside of the shed housing the airship. More than 100 tons of sulphuric acid, 60 tons of iron turnings, and hundreds of tons of water were needed for the process. Before being admitted to the balloon the gas had to be thoroughly cleansed and purified to make it as light as possible and eliminate all acids that might destroy the costly fabric of the balloon. This was accomplished by "washing" the gas, or passing it through water, and subsequently drying it by again passing it through cylinders filled with coke, permanganate of potash, and calcium of lime. As pure hydrogen is odorless and gives no sign of its presence when escaping, several gallons of oil of peppermint were used to perfume it in order to immediately detect leaks. The cost of inflating the America exceeded $5,000.

Type of Construction. The type of construction employed was what is known as the "semi-rigid" similar to the Gross (German) dirigible, *i.e.*, a rigid suspension depending from a flexible gas container. The car measured 156 feet in length and consisted of a truss of triangular section, built up of light steel tubing shown in Fig. 21, and more in detail in Fig. 22. The bottom chord of this truss was a cylindrical steel tank with pointed ends, 75 feet long, employed for carrying the main supply of gasoline, and having a capacity of 1,500 gallons. At the top of the truss a series of transverse brackets was placed, the bag being attached to the car by means of rope connections between the ends of these brackets and a strong band, or web, formed on the envelope itself. This *relingue*, as the French

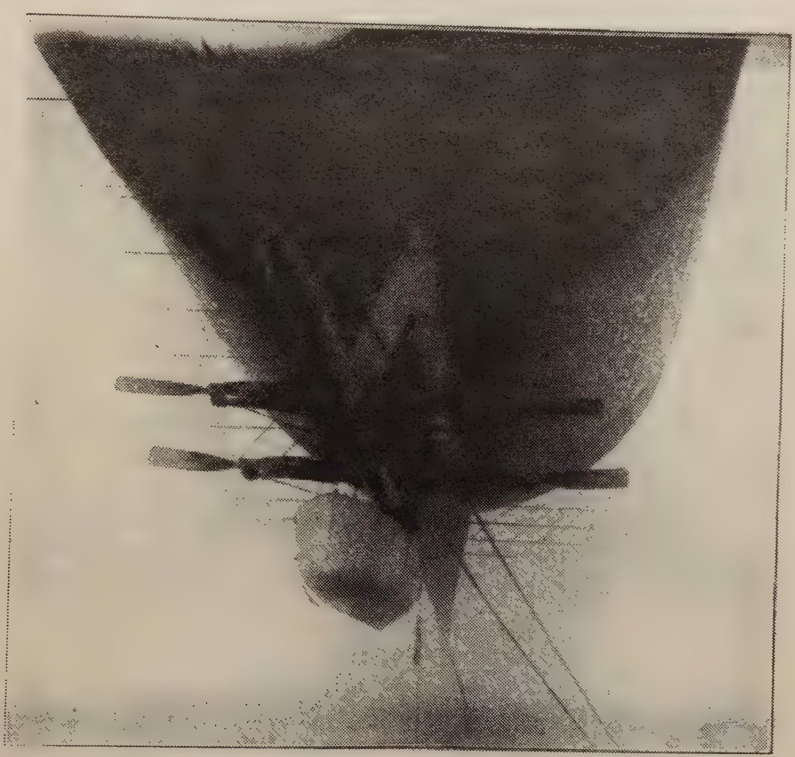


Fig. 21. Wellman's Airship "America," Showing Arrangement of Car

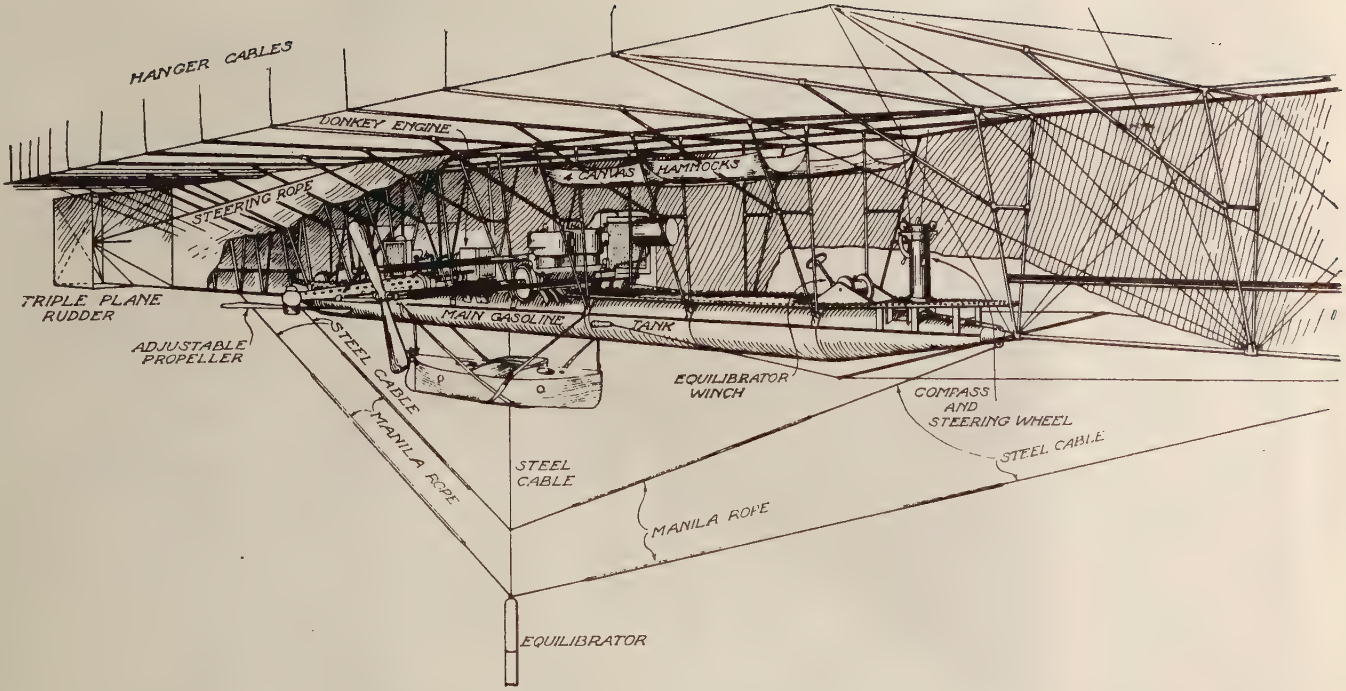
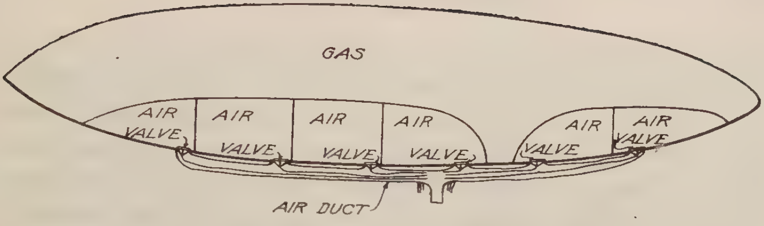
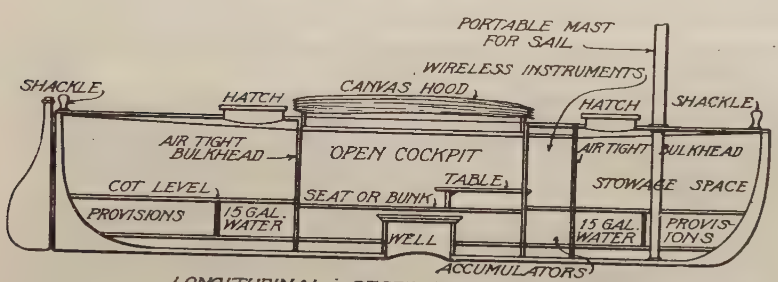


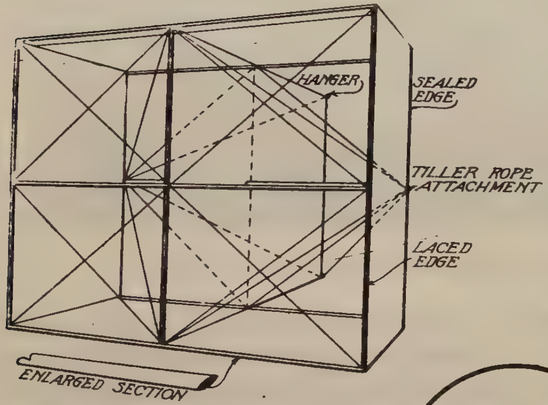
Fig. 22. Structural Details of Car and Accessories of the "America"



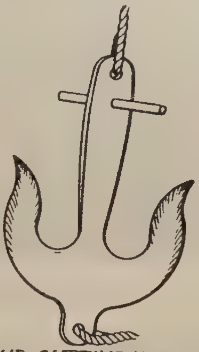
LONGITUDINAL SECTION OF BAG, SHOWING
LOCATION OF BALLONETS WITH VALVES



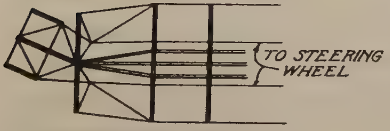
LONGITUDINAL SECTION OF NON-SINKABLE
LIFE BOAT



TRIPLE PLANE RUDDER



THE CUTTING KNIFE
FOR CUTTING OPEN GAS
BAG IN EMERGENCY



PLAN VIEW OF
TRIPLE PLANE RUDDER

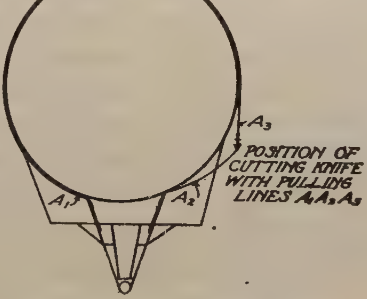


Fig. 23. Details of Balloonets, Lifeboat, Rudders, etc., of Wellman's Airship

term it, was sewed to the fabric about ten feet below the horizontal axis of the balloon. For an emergency descent, there was a "ripping knife," Fig. 23, shaped like an anchor and attached to a rope leading to the car. Pulling this would have cut the gas bag practically in half. From the gasoline tank fore and aft, the bottom chord consisted of tubular extensions. To stiffen the gasoline tank laterally, stays were run from the ends of the extensions to horizontal cross-pieces at the ends of the tank and thence back to the body of the tank, Fig. 22. Further reinforcement was obtained by means of numerous wire cable stays, the whole practically forming a bridge which in places was said to be capable of withstanding a stress of as much as 10 tons. No net, or hood, was employed on the gas bag to add to its resistance in motion through the air, the external surface of the balloon being as smooth and tight as a drum head. The car and its machinery were attached to the band on the balloon by 188 hemp lines, attached at as many points on this band and terminating in eyes from which hung the cradle of suspension cables passing under the car. The latter was entirely closed by walls of canvas pierced by several celluloid windows, Figs. 24 and 25, while several canvas bunks were hung from the transverse braces directly beneath the under side of the gas bag, Fig. 22.

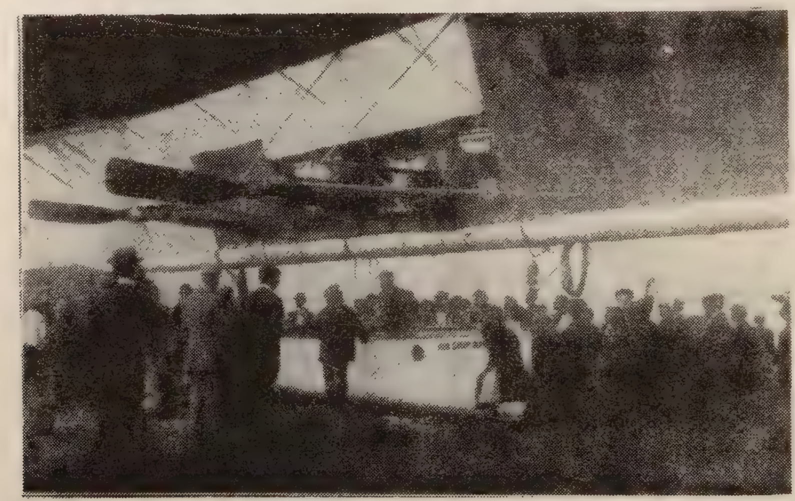


Fig. 24. View of Car Showing Propellers and Canvas Covering

Motive Power. The motive power consisted of two engines, the forward one of which was a Lorraine-Dietrich four-cylinder, water-cooled automobile motor rated at 80 to 90 horse-power (the one at the right in Fig. 24) and weighing with its radiator and equipment close to 1,000 pounds. It drove a pair of wood screws, 12 feet in diameter, at 500 r.p.m. The other, Fig. 26, was an E.N.V. eight-cylinder aeronautic motor rated at practically the same power, and driving a second pair of screws 10.5 feet in diameter at a speed of 750 r.p.m. In both cases, the screws were carried on long shafts extending outboard and constituting extensions of the crank shafts of the motors—in other words, they were direct connected. In the case of the after pair of screws, they could be utilized either to propel the ship forward, as shown in Fig. 24, or they could be employed to assist either in its ascent or descent, due to the fact that they were driven through the medium of bevel gearing at the ends of the engine shafts and could be adjusted so as to exert their force in any direction included within an arc of 180 degrees, Fig. 26. This expedient was adopted to take the place of the stabilizing planes usual in French construction, or the sliding weight of Zeppelin's airships. It was

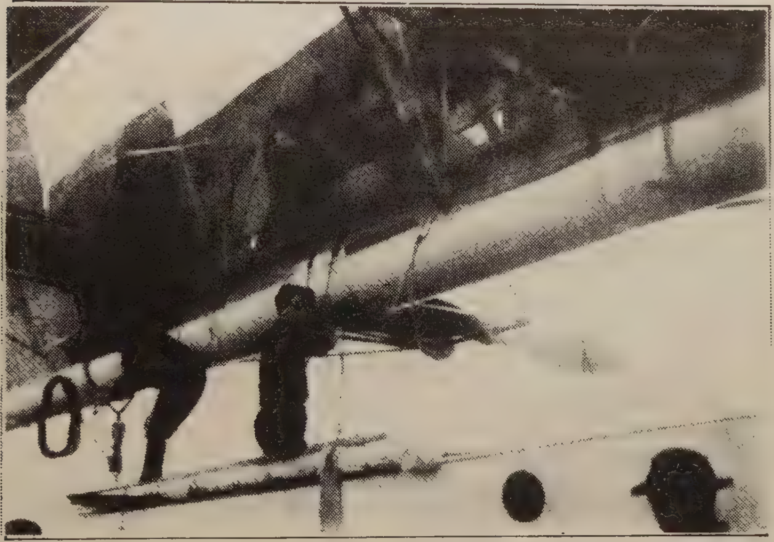


Fig. 25. Close View of Car Showing Windows and Long Gasoline Tank

made possible through the ingenious invention of Chief Engineer Vaniman. As already mentioned, the drive between the shaft and propeller was through miter gears. The shafts themselves were carried in conical supports projecting out from the sides of the car, and these supports were capable of being revolved through the medium of worm gears and hand wheel. As the propeller shaft is turned through an angle, the gear it carries is free to travel on the gear keyed to the power shaft.

In addition to these two motors, there was also a third, or "donkey engine," to revert to marine parlance. This was a small four-cylinder, vertical, water-cooled, gasoline motor rated at 10 to 12 horse-power. It was intended for a number of purposes, one of the most interesting of which was cranking the larger engines to start them. To accomplish this, the donkey engine shaft was geared to the shafts of the larger motors by means of clutches which automatically released as soon as the large motor started. This small engine also served to drive the pumps for inflating the air-balloonets, the arrangement of the latter being clearly shown in Fig. 23. There were six in all, four placed forward and two aft, and all were fed with air from a common duct. Each balloonet, however, was provided with its own individual valve, so that the distribu-

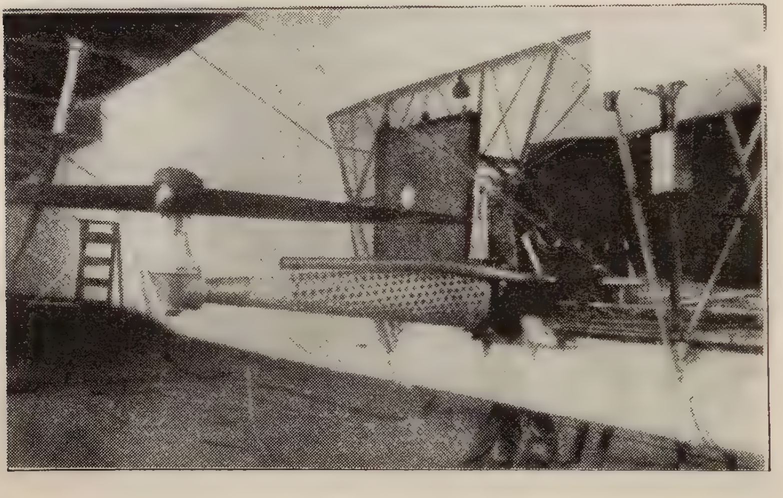


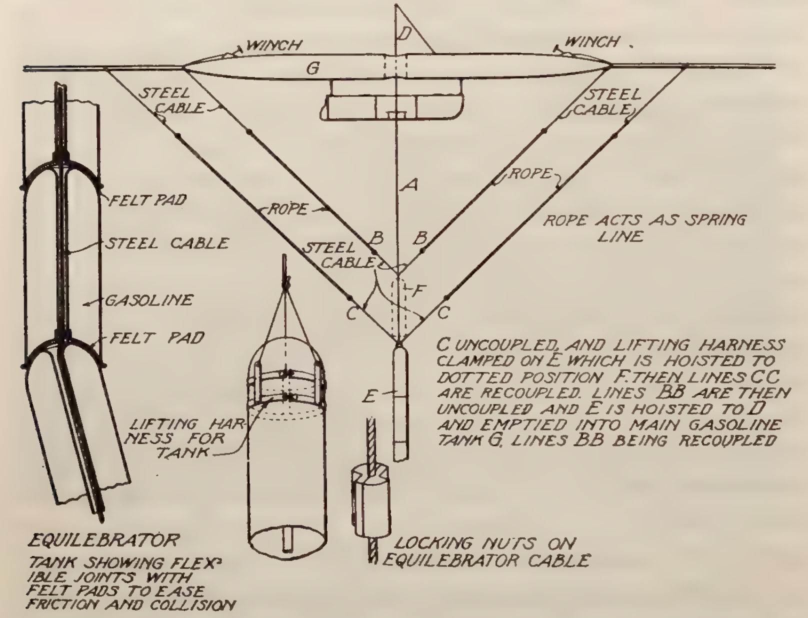
Fig. 26. View of Rear Propellers Set Horizontally for Lifting the Airship

tion of the air ballast could be controlled and the ship kept on an even keel.

Accessories. The rudder consisted of three vertical planes, Fig. 23, the center plane being broader than the other two, which were set back a few feet so that when the rudder was turned sharply to one side or the other, the plane at the inner side of the turn would neither come in contact with the balloon, nor screen the center plane, thereby cutting off its resistance to the air. The bunks already mentioned were only in the form of extra accommodation, the main sleeping quarters being in a lifeboat suspended beneath the car, Fig. 24, and providing accommodation for the crew of six, consisting of Walter Wellman, who was responsible for the undertaking, Melvin Vaniman, chief engineer, Murray Simon, navigator (junior officer of the steamship Oceanic), J. R. Irwin, wireless telegraph operator, and two mechanics. This lifeboat, shown in section in Fig. 23, was specially constructed for the purpose so that while it had an overall length of 27 feet by 6 feet beam, its total weight was only 1,000 pounds. This was accomplished by making the hull of layers of mahogany veneer and canvas, giving it the appearance of being built of solid wood. Two watertight compartments were provided fore and aft, and the boat was self-bailing so that it could keep afloat in the heaviest sea. There was no power in the boat, but a jury mast and sail were carried along, together with an ample stock of provisions and water, so that in case of abandonment it would be possible to keep afloat for a considerable time. Through the center of the boat was an upright steel tube through which the equilibrator passed.

The wireless apparatus of the expedition was installed in a forward compartment of the boat so that it could be employed both while in the air and after the airship had been abandoned. That is, as long as the current held out. The radius of action of the instruments was about 100 miles, and they were provided with current from a small set of storage batteries kept charged by a dynamo driven by the donkey engine. Current from this battery also provided electric lights for the car and boat. In addition to this, there was a telephone system between the boat and car. As it would undoubtedly be necessary to get away quickly in case the airship had to be abandoned in an emergency, the boat was suspended on special self-releasing hooks, so that by cutting a single rope it could be dropped instantly. That this was a ticklish maneuver even under very favorable conditions was shown by the actual rescue of the crew.

It was rendered so by the presence of the equilibrator which did not act quite as effectively in practice as its theory would indicate. Its purpose was to take the place of the usual drag rope carried by the ordinary spherical balloons in drifting. As in view of the tremendous lifting power of the America, it would be necessary to provide a drag rope of considerable weight, advantage was taken of this to make of the equilibrator a sort of automatically compensating balance, hence its name. In fact, it took the place of the ballast ordinarily carried. To give it sufficient weight, it was made of 30 short steel cylinders, each of which was convex at one end and concave at the other, and, as is made clear by the detail view, Fig. 27, the convexity of one tank seated in the concavity of the next, forming a sort of universal joint. This whole series of tanks had longitudinal holes running through their centers and were strung on a heavy steel cable, or flexible wire rope. To prevent one tank from damaging



C UNCOUPLED, AND LIFTING HARNESS CLAMPED ON E WHICH IS HOISTED TO DOTTED POSITION F. THEN LINES CC ARE RECOUPLED. LINES BB ARE THEN UNCOUPLED AND E IS HOISTED TO D AND EMPTIED INTO MAIN GASOLINE TANK G. LINES BB BEING RECOUPLED

EQUILEBRATOR TANK SHOWING FLEXIBLE JOINTS WITH FELT PADS TO EASE FRICTION AND COLLISION

Fig. 27. Diagram Showing Construction of Equilibrator and Method of Suspending it from the Car

the next a felt packing was placed between them and the passage for the cable through the convex portion was flared, or bell-mouthed, so that there would be no danger of shearing the wire rope.

At the end of the series of tanks, a series of 40 wood blocks, each 20 inches long, was strung on the cable, forming a sort of "rat tail" to protect the lower end of the equilibrator by taking the shock of suddenly striking the water. The total length of the equilibrator was 330 feet and the steel tanks were utilized to carry an extra supply of gasoline. The joints between these tanks made it so flexible that, in the space of four tanks, it could be turned at right angles without injury. At its lower end, the wood blocks tapered from about 10 inches in diameter, down to 4 inches at the extremity. Owing to its great length it was utilized as the antennae of the wireless outfit, in addition to carrying a supply of fuel.

The purpose of the equilibrator was to avoid the necessity of carrying sand ballast to counteract temperature changes and eliminate any occasion for permitting gas to escape. The lower end was designed to trail on the water and be supported by it and to guard against losing it in stormy weather, the construction was such as to withstand a heavy sea. This was naturally made necessary by the fact that each of the tanks with its store of gasoline weighed about 100 pounds, making the total weight in excess of 2 tons. The latter was really ballast with a string attached to it, for as the balloon descended more of the equilibrator would rest on the water and a correspondingly increasing percentage of its weight would be water borne, thus relieving the airship and increasing its lifting force in proportion. When the balloon tended to rise, it was first necessary to lift the entire length of the equilibrator out of the water before its height could exceed 330 feet in the air. As soon as this took place, the entire weight of 2 tons or more acted as ballast to prevent the balloon rising to a great height.

To appreciate the importance of this arrangement in its bearing upon the ability of the America to stay in the air, it is necessary to realize what extremely variable atmospheric conditions are met with and what their effect is on the balloon. Hydrogen gas expands or contracts $\frac{1}{491}$ part of its volume for every increase or decrease in temperature of 1°F. Gas within a balloon subjected to hours of warm sunshine will store heat in much the same manner as a greenhouse does, and when a poor conductor of heat such as rubber is present as in the fabric of America's envelope, this is accentuated as more of the heat is retained and the gas accordingly becomes much warmer than the surrounding air outside. Assuming that the gas reached a temperature of 100° F. during the afternoon, which could hardly be avoided on a bright day even in Fall, and then dropped to 50° during the night, it would involve a contraction equivalent to one-tenth of its volume. This represents an extreme case, but a variation of one-twentieth was quite probable. With the America, that would mean a loss of approximately 1,200 pounds of lifting force. In other words, to prevent settling, an equivalent weight must be subtracted from the load. Coming down would cause an increase in the atmospheric pressure, still further contracting the gas, while a rain storm might augment its load by depositing anywhere from 500 to 1,000 pounds of water on the 4,000 square feet of surface presented by the envelope. Assuming that this has occurred during the night and that the following day is bright, exactly the opposite of these conditions will obtain. The sun will dry out the envelope, expanding the gas until the air is driven out of the balloonets through the automatic pressure valves and the lifting power is greatly increased. There will then be a strong tendency to rise and, under ordinary conditions, the only means of counteracting this would be to permit the escape of gas.

This would reduce the sustaining power of the balloon during the next period of contraction, so that without special means of guarding against the necessity of sacrificing ballast to prevent coming to the earth, and gas to avoid getting too far away from it, the voyage would naturally be limited to a very short period—not more than two or three days at the most. It would also involve carrying a great deal of ballast, thus sacrificing the amount of fuel that could be taken. Were the ship to rise to any great height, there would be the danger of coming down too fast should the gas suddenly begin to contract, and the momentum gained in descending from a great height could be overcome only by relieving it of a great deal of weight.

The equilibrator, on the other hand, was designed to maintain the America between 100 and 200 feet above the water. The ballast automatically "thrown overboard" when the ship dropped lower was again picked up when it was needed and in the same manner. This meant saving gas and augmenting the quantity of fuel that could be carried, making it possible to prolong the voyage from the forty-eight-hour limit otherwise practicable to the eight or ten days that were thought to be necessary to cross the ocean. In theory, the device appeared to be entirely practical. As a matter of fact, this was not the first time it had been tried, having been employed on the original America, in which Wellman made an attempt to reach the North Pole a couple of years previous. In this instance, the conditions were entirely different, one of the chief requirements being an ample supply of provisions, as the explorers might be lost for several months. The equilibrator, therefore, took the form of a long leather tube which constituted the drag rope, and in which the food was carried. The limited experience with it under favorable weather conditions in the Arctic showed that it rode smoothly, and, being a continuous body, it did not offer any substantial resistance when towed. Unfortunately, it dropped into the ocean within two hours after leaving Spitzbergen, thus depriving the expedition of its supplies. This leather food bag was the predecessor of the equilibrator.

To cross the Atlantic, what was most needed was food for the motors. Their combined power only sufficed to drive the America at a speed of 26 miles an hour, while one of them could propel her at the rate of 20 miles an hour. But as each motor consumed 1,000 pounds of gasoline per day, it was intended to keep only one in operation, holding the other in reserve, and also for emergency purposes when necessary to prevent being driven back by contrary winds. With the above speed as the basis, it would require six days to cross the Atlantic in a perfect calm or its equivalent, *i. e.*, the favoring winds of one day neutralizing the contrary air currents of other days. To allow ample margin, ten days travel was provided for, thus making it necessary to carry 10,000 pounds of gasoline, or 5 tons. Of this quantity 4 tons were carried in the steel tank forming the foundation of the car, and the remaining 2,000 pounds in the equilibrator.

The equilibrator passed down through the center of the car, and through a well in the center of the lifeboat, as shown in Fig. 22. It was supported by a pair of steel cables running forward and another pair running aft. To provide a certain amount of flexibility, sections of Manila rope were introduced into the steel cables as indicated. To be able to utilize the supply of gasoline in the tanks, a pair of winches, Figs. 22 and 27, were provided to haul the upper pair of cables in, taking the strain off the lower pair so that they could be disconnected by a number of the crew let down in a "bosun's chair." The uppermost tank was then hoisted and the cables made fast again below it. Then the upper cables were slackened and detached to permit of drawing the tank up into the car. Contrary to what might appear to take place, in pulling in on the winches, the equilibrator would not be hoisted but the airship drawn down.

In the forward end of the car was placed the navigator's bridge, where the compass, leeway indicator, and the steering wheel were placed, the latter being connected by light steel cables to the triplane rudder of steel tubing and canvas. Here also were placed the meteorograph, an instrument to record combined atmospheric phenomena, the barograph (altitude recorder), and the thermograph (recording thermometer), as well as the statoscope (a form of aneroid barometer having a large air reservoir and highly responsive to minute fluctuations in pressure). Speaking tubes led aft to the engine room. The problem of navigating the ship was naturally no easy matter. While its position would be ascertained from time to time in the usual manner, by the aid of the sextant and chronometer, its actual course at any time would be hard to determine. For instance, if it were traveling east at 20 miles an hour, and the wind were blowing south at the same speed, its actual course would be southeast, although the compass indication would be east. Wind vanes or similar instruments would be of no assistance as they would have no connection with the sea as a basis from which to determine the direction of motion, though this could be obtained by means of a log line let down from the lifeboat. As it was not desired to reach any particular port, there was no great necessity for accuracy in navigation, the only aim being to get across the ocean.

Akron. It was with no feeling of regret that Melvin Vaniman, leaning over the taffrail of the steamer Trent, watched the ill-fated America sink slowly to the sea. It might be supposed that the engineer who had spent so many years of work on this dirigible would entertain some sentimental regard for the old balloon. But Vaniman's thoughts were already centered on another expedition in which he would not be hampered with old material, an old gas bag and old engines, but could plan an entirely new airship made of brand new material and exactly as he wanted it. The America had served its purpose well, and from her the lessons had been learned that were necessary to make a future airship successful.

When the America was abandoned, it was structurally sound, showing that the principles involved were correct. One part only had failed: A key worked loose in one of the propellers, as already described, depriving the airship of the use of the horizontal propellers, and to this defect Vaniman attributed the failure of the expedition. Contrary to public opinion, Vaniman's faith in the equilibrator, or its equivalent, was not shaken. Its action in the sea, its defects and good qualities were all known after this voyage, and it was from this experience that he got to the heart of the problem, viz, the designing of a device that would serve the purpose of the old equilibrator without the latter's defects—a device that would have changeable and not a fixed weight, in other words, an equilibrator that could be made heavy or light at will.

The new expedition has been financed by F. A. Sieberling, president of a large rubber goods manufacturing concern, and the envelope of the Akron was made in the Ohio city after which it is named, under Vaniman's personal direction. It differs considerably from that of the America, being much longer and of smaller diameter, Fig. 28, with a tapering stern, instead of the former blunt-nosed, double-ended form. The old hangar at Atlantic City was impressed into service again, but the 268-foot length of the new ship exceeded its housing capacity by 10 feet, and, rather than enlarge the building, which could have been done only at considerable expense, this much of the balloon was sacrificed, the dimensions of the latter thus being 258 feet overall, by 47 feet in diameter. Below the balloon is suspended a car similar in shape to that of the America, but considerably longer. The body of this car forms a steel tank capable of carrying 5 tons of gasoline, and on this tank a platform constituting the floor of the car is built. To drive the airship, three engines are provided, one of 100 horse-power, placed forward and fitted with two propellers adapted to revolve only in a vertical plane, and two others of 100 and 80 horse-power, respectively, farther aft. These two motors are fitted with propellers which may be revolved at any angle between the vertical and horizontal planes,

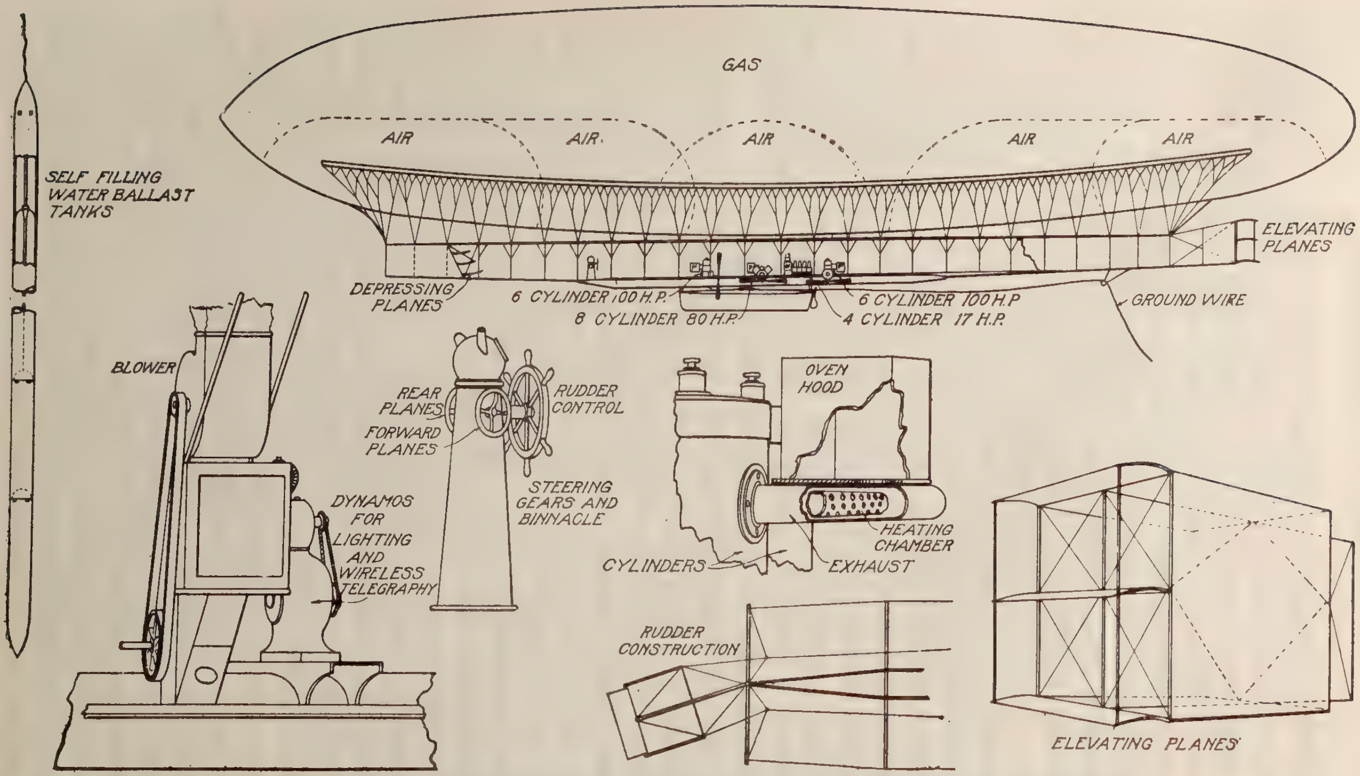


Fig. 28. Diagram of Vaniman's Airship "Akron" Showing Details of Some Novel Control Devices

being adjustable through an arc of 180 degrees by the aid of a bevel driving arrangement similar to that on the America, and designed to enable the thrust of these propellers to be utilized for raising or lowering the airship. Normally, only the forward motor will be employed to drive the ship ahead and, from the results of the short trial trips made, there seemed to be no reason for believing that the speed of 30 miles an hour for which the ship was designed when running under this one motor, would not be realized. Under full load, this motor consumes about 60 pounds of gasoline per hour, so that the supply of 5 tons should last a week.

When utilizing the forward motor alone for driving, the propellers of the other two motors will be feathered, or adjusted horizontally so as to present the minimum surface to the wind, thus keeping down the head resistance. In addition to the engines in question, there is also a 17-horse-power motor directly coupled to a dynamo to supply electric current for lighting and for the Marconi wireless equipment, Fig. 28. It also operates the blower for filling the air balloonets and drives a countershaft from which any of the larger engines can be started by power. Two of the larger motors are of the six-cylinder type, the other being an eight-cylinder, while the auxiliary motor is a four. Benefiting from the experience on the America, the envelope of which was in constant danger of being set afire from the exhaust of the motors, the engines of the Akron are equipped with specially-designed mufflers attached directly to the manifold. One of them is fitted with an oven for use in cooking, Fig. 28.

Substitute for the Equilibrator. According to Vaniman the crux of the problem lies in the ability to keep the airship down at a moderate level. It is an easy matter to design an airship that will have sufficient carrying capacity to cross the Atlantic, but the difficulty is to maintain the airship at a constant moderate elevation above the water during the voyage. The equilibrator having failed signally to do this in accordance with its theoretical promises, it has been abandoned, and the height of the Akron is designed to be controlled by taking on water ballast; also by the use of stabilizing planes fore and aft, while in case of emergency, the elevating and depressing propellers, which have been doubled in number and power, can be resorted to. As shown by the sketches, Fig. 28, there are three planes on each side of the car, those forward being curved upward, thus constituting depressing planes, while those at the rear are curved downward and are designed to be employed as elevators. The latter are mounted on the rudder. These planes may be tilted to any angle desired and serve to keep the airship on an even keel. When dipping down to take water, the forward planes will be used for depressing the bow, and the rear planes for elevating the stern. These planes are separately controlled by hand wheels on either side of the binnacle, as shown in the detailed sketches of the steering gear in Fig. 28. The level of the ship may further be controlled to a considerable extent by inflating the balloonets forward at the expense of those in the rear, when it is desired to make the bow heavier than the stern, and *vice versa.* To scoop up water ballast, it will be necessary to drive the ship down near the level of the ocean, which may be done by tilting either pair of adjustable propellers to the proper angle. The only object in having two sets of adjustable propellers is to provide an extra set for reserve. The device with which water ballast is scooped up is somewhat similar to the equilibrator used by Wellman. It consists of tanks about 6 inches in diameter and 24 inches long, strung upon cables exactly as were the gasoline tanks of the equilibrator, Fig. 28. These ballast tanks are provided with openings near the upper end of each so that by dragging them in the sea, they will scoop up water. There will be three sets of tanks strung on separate cables, and under normal conditions they will not hang from the car as did the equilibrator, but will be stored in the body of the vessel. When taking up water for ballast, if the wind be strong, the airship will be headed into the wind and the tanks will be trailed from a point aft of amidships, so there will be no tendency for the airship to nose down into the sea. It is planned to maintain the Akron at an elevation of between 200 and 1,000 feet at the outset of the voyage, but as the airship is lightened by the consumption of gasoline and provisions, it may rise to much greater heights. During the daytime, it will have to be heavily water-ballasted in order to hold down to these levels when the gas in the balloon is expanded by the heat of the sun. At night, this ballast will be emptied overboard to compensate for contraction and the consequent reduced lifting capacity of the balloon.

Suspended below the Akron is the same lifeboat in which the crew of the America made their escape, but its construction has been materially altered to facilitate launching as well as the greater comfort of the crew. The well in the center has been eliminated as there is no longer any equilibrator to pass down through it. A much larger wireless equipment with a sending range of 500 miles is also installed in the boat, a ground being provided by trailing a wire in the sea. The crew of the Akron numbers seven men all told, consisting of the commander, navigator, helmsman, wireless operator, two engineers, and one extra man for general work. Provisions are carried for a cruise of twenty days. The original intention was to start in October, 1911, but so many causes of delay arose that the Akron was not ready for its first trial trip until November. Several trial trips were made, one or two of which were marred by slight accidents, though generally successful, so that it was decided to postpone the start until the following spring.

The navigation of a dirigible is a much more difficult thing than that of a steamer, as both the speed and the direction of travel are more or less uncertain. Had it not been for the equilibrator dragging in the water, the crew of the America would not have known that she was traveling broadside on, after the motors were finally stopped for good, nor how fast they were going. In fact, as the dirigible without its motors is simply an old-type balloon that drifts with the wind as if it were a part of it, there is no sensation of movement whatever and naturally none of direction when over the open sea, for want of fixed objects to use as points of observation. In this connection, Vaniman has devised a number of interesting instruments which will indicate the direction of travel and likewise the speed of the airship. One of these consists of a combined camera and compass, the camera having its ground glass divided into equal squares. By noting how long a "fixed object" on the water below takes to pass across a given number of squares, in connection with the altitude as indicated by the barometer, it will be possible to calculate definitely by means of triangulation the speed at which the vessel is traveling, and, by reference to the compass, the direction of travel. At first sight, it would seem as if this method would fail for want of a fixed object to observe, but it will be recalled that though waves travel, the water that forms them is practically stationary. Hence, the foam of a white cap may be considered as practically a stationary object while it lasts. In addition, Vaniman has also developed a special type of sextant for use on the expedition.

"Wire-Wound" Fabric. The fabric employed in the making of the envelope of the Akron is said to be the strongest ever employed for the purpose, so that by continually pumping air into the balloonets, air ballast can be added and the ship brought down from a considerable height. The value of this feature was strikingly shown in one of the trial trips when the airship was brought down in this manner from a height of 2,000 feet, after an accident to one motor and the breaking of the propeller shaft of another.

This powerful control over the gas led Vaniman to make a further study of the subject and he calculated the strength of a fabric necessary to resist the increased pressure in the envelope due to a rise in temperature of 50 degrees F. With only a small factor of safety, it was found that the tensile strength necessary was 1,000 pounds to the square inch, or 18 tons to the yard. To obtain this increased strength, a special fabric interwoven with fine piano wire must be employed, the wires running longitudinally and circumferentially without cuts or joints, so that their maximum tensile strength may be relied upon, the longitudinal wires being spaced $\frac{1}{16}$ inch and the circumferential wires $\frac{1}{32}$ inch apart. This fine mesh renders the envelope both fireproof and lightning-proof on the principle of Davy's safety lamp, while this great wire cage will doubtless serve as an excellent antenna for wireless work. On an airship of the Akron's size, the increased weight due to the wire is about $2\frac{1}{2}$ tons.

The additional weight of the wire would reduce the net lifting power of a ship of this size from $7\frac{1}{2}$ tons to 5 tons, but the advantages obtained would warrant the sacrifice. In comparison with the weight of the rigid dirigible construction, this net carrying capacity is remarkable. The latest Zeppelin built in 1911, the Schwaben, with 680,000 cubic feet of gas, has a net lifting capacity of $2\frac{1}{2}$ tons, while a ship of the size of the Akron with a steel-reinforced gas bag holding only 400,000 cubic feet of gas would have a net capacity of 5 tons. The ability of the "wire-wound" envelope to withstand such heavy pressures would automatically take care of the great problem of expansion and contraction, giving a powerful control by enabling the pilot to change altitude without loss of gas or ballast and without depending upon planes or motive power.

Vaniman plans to build a dirigible of the size of the Akron, using this new "wire-wound" fabric during 1912.

Inflating the Akron. As the new Vaniman airship has a capacity of 400,000 cubic feet of gas, no small problem was involved in the manufacture of sufficient pure hydrogen gas to properly inflate it, as the lifting power of the gas is not alone proportional to its purity, but the presence of acid fumes or other adulterants would be ruinous to the fabric of the envelope and particularly to the numerous seams. To carry out this important undertaking a special plant was built just outside of the big shed at Atlantic City. Making allowance for waste and condensation, sufficient material was purchased to manufacture 450,000 cubic feet of hydrogen. This consisted of 80 tons of scrap iron and 100 tons of sulphuric acid. It will be noted that Vaniman has introduced a number of innovations in this gas plant, as compared with the usual method, so that there is no interruption in the generating process. As shown in the plan view, Fig. 29, there are four generator tanks *A*, made of wood with all iron parts well coated with pitch to prevent their being attacked by the acid. These tanks are partly filled with scrap iron, Fig. 30. The sulphuric acid is fed from one of the two large reservoirs *B*, Fig. 29. Running over these reservoirs is a track *C*, on which the sulphuric

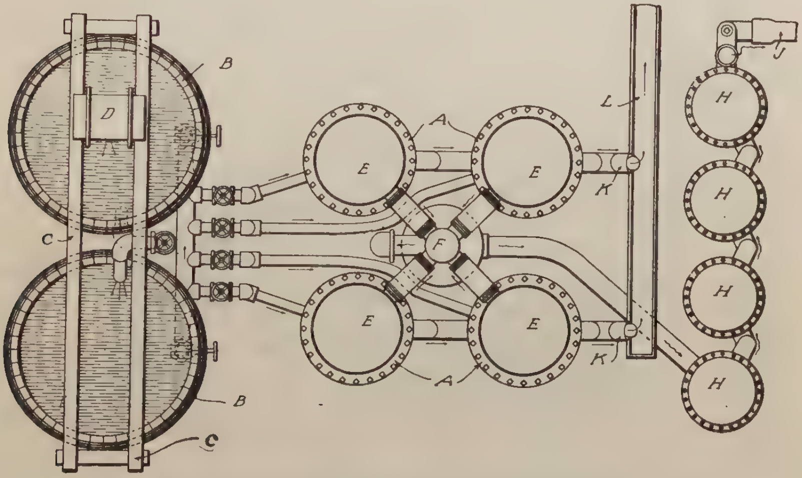


Fig. 29. Plan View of Vaniman's Hydrogen-Generating Plant

acid casks *D* are supported. To prevent too rapid generation of gas and the choking of the tanks with ferrous sulphate, the acid is diluted in the proportion of one part to eleven parts water. While this mixture is being prepared in one of the reservoirs the supply is drawn from the other. This solution takes the course indicated by the arrows to the bottom of the generator tanks, and it may be caused to flow directly into any one of these tanks or from one pair of tanks to the other, this being a more economical method as it insures complete utilization of every bit of the acid. The gas generated in the tanks rises to the top, where it is trapped by the gasometers *E*

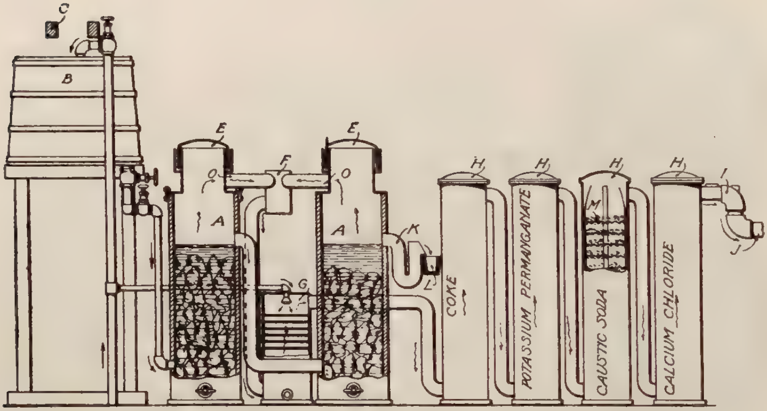


Fig. 30. Side View of Vaniman's Hydrogen-Generating Plant, Somewhat Distorted to Bring Purifying Tanks into View

and flowing into a common chamber *F* passes down to the washer *G*, Fig. 30. Here it is forced to pass upward through a series of perforated plates, while a spray of water flows downward through the same plates. Thence, the gas passes through four tanks *H*, the first containing coke, the second potassium permanganate, the third caustic soda, and the fourth calcium chloride. The first two serve to purify the gas of such materials as arsenic, sulphur, and phosphorus which are likely to be picked up from the iron. The other two tanks serve to remove all traces of moisture from the gas.

Hydrogen is an odorless, colorless gas and it would be impossible to detect leaks in the balloon were not some means employed to impart an odor to the gas. The "perfume" commonly used is muronine. This is placed on a sponge in the pipe *I*, and thence the gas is fed directly into the balloon at the tube *J*. The substance in question has a most penetrating, sickish odor that can be readily detected, no matter how small the leak may be.

One of the advantages of the arrangement of this plant is that when it is desired to charge one of the generators with fresh scrap iron, it may be cut out of the system completely by shutting the valve in its connection and by clamping the rubber hose connecting the gasometer of that particular generator with the chamber *F*. The spent solution flows from the generators through traps *K* to a trough *L*, which leads to a large drain. Heretofore, the purifying and drying tanks have been filled with coke on which the various cleansing chemicals were sprinkled, the purpose of the coke being to prevent the materials from clogging. This method has caused much trouble as the materials would slowly gravitate to the bottom of the tank, choking the flow of gas. Whenever such a condition arose, it was necessary to shut down the entire plant and clean out the tanks. Vaniman employs instead a set of trays of copper netting secured to iron straps, as indicated at *M* in Fig. 30, and on these trays the purifying and drying materials are placed. Thus the mass is kept in a porous condition, through which the gas can easily percolate, and, in case of any trouble, the entire set of trays can be lifted out bodily. It was necessary to operate the plant for five days and nights continuously, the hydrogen weighing more than a ton, or about half as much as that of the three-ply cotton and rubber fabric of the envelope. Some idea of what this amount of gas means may be gained from the fact that its equivalent in coal gas fed to an ordinary five-foot burner would supply it for more than ten years constant burning. The lower part of the illustration shows a true plan view of the gas-generating plant, while the upper part is a somewhat distorted section, drawn in this manner to more clearly illustrate the passage of the gas in the course of its generation and purification. The cost of this plant, plus that of the material necessary to inflate the Akron but once, would be sufficient to pay for several modern aeroplanes.

ACHIEVEMENTS OF THE DIRIGIBLE

The year 1910 will go down in history, not alone as marking the first actual transportation of passengers through the air for hire, but likewise the first attempts to cross the Atlantic in an airship. Two of these attempts were proposed and one was actually undertaken. This was the ill-fated cruise of the America, already described, but the failure of its promoters to achieve their object has proven no deterrent to others intent upon accomplishing the same feat. In fact, 1910 may be said to mark the beginning of an era of aerial transportation, as while the wreck of the Zeppelin after having made but comparatively few trips, put a sudden end to the much advertised "regular passenger service" for the time being, neither this nor the subsequent wrecking of other Zeppelin airships proved sufficient to discourage the promoters. During 1911, the Zeppelin and several other German companies formed for the purpose carried hundreds of passengers, and it is a fact worthy of note that since the latter part of that year, one of the large steamship companies has combined announcements of aerial trips with those of the sailing of its steamers; and tickets good for flights in Germany can be bought in this country. The success of the German dirigible passenger service has been such that, in spite of the numerous disasters which have fortunately been free from fatalities, a similar service is to be instituted in this country, using German airships at first.

Wellman's Expedition. Owing to its novelty, as well as its daring, the attempt of Wellman to cross the Atlantic in the America, is worthy of record, particularly as his failure has not deterred others from attempting the same feat, and doubtless it will not be very long before it is actually accomplished. What such an accomplishment will show, however, apart from the fact that the aeronauts met unusually favorable conditions, is questionable. In order that the appended account may be free from the sensational coloring given the America's trip by the newspaper and magazine reports, excerpts are taken from the story of Vaniman, the chief engineer, though it is to be noted that his version exhibits some irreconcilable differences with that of Wellman himself.

The start was made at 8 A.M., October 15, 1910, from Atlantic City in a light southwesterly breeze, there being considerable fog.

The attempt was really premature and probably would not have been made at that time, had it not been for the question of good faith on the part of Wellman raised by the press. So many delays had been experienced that the date of starting had been constantly postponed from month to month and Wellman was accused by inference, if not openly, that he had no intention whatever of ever making the attempt. The actual start was accordingly made under unfavorable conditions and without any previous trials of the airship that would doubtless have revealed the defects later brought to light when there was no possibility of remedying them. Everything had apparently been in a state of readiness for weeks prior to the start, but this was not actually the case, and while numerous indoor tests of the machinery had been made this was not the equivalent of actual trials in the open. The "after" engine, as already explained, was arranged to drive its two propellers through the medium of bevel gearing so that the propeller shafts, which were at right angles to the extended shafts coupled to the engine, could be swung bodily about in a complete circle, thus making it possible to employ their thrust in any direction desired, but more particularly in a vertical line so as to force the balloon up or down. The fatal mistake consisted in not supplying this engine with a flywheel. For four hours it operated steadily, not missing more than two explosions in this entire period, but the absence of the flywheel (for which it had been designed and the loss of which was not compensated for by the propellers) produced a pounding action, and the keys of the bevel gearing worked loose, rendering the engine useless. How serious this loss was could not be appreciated until the next day, as will presently be explained.

During Saturday evening the airship was in danger of being blown onto the shore of Long Island by a southerly shift of the wind, and it was necessary to use the engine to keep her headed off shore. The fog still persisted and it was feared that the two-ton equilibrator trailing in the water would strike some vessel, resulting in immediate disaster to the airship, as it would draw it down into the sea; furthermore, it might do a great deal of damage to the vessel encountered. The moon was full but owing to the fog it was impossible to see anything ahead. Two lookouts were stationed to endeavor to prevent collisions. Suddenly the sound of a fog horn was heard, and almost immediately the masthead of a schooner loomed up dead ahead. But the airship responded beautifully to its helm and swung to one side, just clearing the vessel by a narrow margin. This experience as recounted later by the captain of the vessel was most thrilling. He had no knowledge of any contemplated voyage across the ocean by airships, and he was greatly frightened when the monster loomed up out of the fog with the sparks streaming from its red-hot exhaust pipes and making a terrific racket with its unmuffled engine. The lashing equilibrator with one tank empty, owing to leakage of gasoline, was being pounded by the water, giving a weird, hollow sound that added greatly to the terror of the crew. This was the only approach to a collision experienced.

Vaniman had no idea that the engine was throwing sparks until this was revealed by the darkness. The exhaust pipe terminated directly back of the propellers, so that the sparks were carried off in the wake of the latter and there was little likelihood of their lodging in the fabric of the balloon. The airship had been traveling through fog ever since morning and was dripping wet, so there was no danger of fire. Sunday morning, the fog still continued and the wind, veering to the west, began to freshen, making it unnecessary to use the engine. But with the freshening of the wind a new danger arose. The airship had started out from Atlantic City with an extra supply of gasoline aboard, so that it hung very low over the water, all but six tanks of the thirty in the equilibrator being submerged. With the freshening wind, it was found necessary to throw over gasoline in order to lighten the airship. Had this gasoline been left behind to start with, the airship would have made much better progress and would have been much farther along when the wind freshened, but the extra fuel was taken on with the expectation that the fog would eventually lift, and under the heat of the sun the gas in the balloon would expand and lift the balloon to its normal position. However, the sun remained hidden by banks of fog.

Sunday afternoon, the wind assumed a velocity of 35 miles an hour. The night grew very cold, shrinking the balloon and making it necessary to throw out more gasoline. Then a peculiar motion began to manifest itself. It will be recalled that the purpose of the equilibrator was to hold the airship at a practically constant level above the sea; in other words, the airship and the sea were to divide between them the burden of supporting the two-ton equilibrator. If the ship showed a tendency to rise, it would be weighted down by having to lift a greater weight off the sea, and if it showed a tendency to descend, it would be lightened by letting more of the equilibrator float, with the result that the airship should be held at a practically uniform elevation above the water. However, when the wind freshened, the drag of the equilibrator began to set up a surging motion. It would pull the airship down, slowly but surely, until it almost touched the water, then the airship would rebound with gathering momentum, pulling the equilibrator out of the water, tank by tank, until it was lifted entirely clear of the surface. The equilibrator would then swing forward like a huge pendulum and, as its weight overcame the buoyancy of the balloon, it would strike the water, and the dragging action would recommence. In this way, the airship kept constantly oscillating up and down, the period of the oscillations being about ten minutes. On one occasion the big balloon swung so near the water that the waves struck the lifeboat cradled below it. There seemed to be no way of preventing this. It was then that Vaniman realized the loss of his after motor, for had he been able to use these propellers to lift the airship when it showed a tendency to be dragged down, the oscillation could have been largely, if not entirely, prevented.

The thrust of the propellers which might thus have been used was 800 pounds, and this would have been more than sufficient to correct the surging movement. Had the airship been further lightened, it might have been able to lift the equilibrator clear of the water when there would have been no drag to contend with and it would have been possible to steer the craft into the wind. As it was, the airship was helpless. It was drifting broadside to the wind. As long as the oscillatory motion kept up, it would have been dangerous to have headed the vessel into the wind, for then it would have pitched badly, tending to stand straight up and down. As long as the wind held from the right quarter, it mattered little whether the engine was used or not, but the oscillations were nerve racking, and not at all calculated to inspire the crew with any feeling of security. The pounding of the waves on the equilibrator, about which so much was published, amounted to practically nothing, according to Vaniman. The jars were not at all serious, but considering the experiences they had gone through, the members of the crew were ready to exaggerate the slightest unusual shock, and the harmless pounding appeared to assume dangerous proportions.

Sunday was a night of grave apprehension. It was found necessary to throw over a quantity of the precious gasoline, as well as the damaged engine (a 90-horse-power automobile motor) in an effort to prevent the airship from being dragged down into the water. Monday, however, the sun rose clear and hot and beat upon the gas bag. There was no wind to counteract the heating effect, because the vessel was drifting with the wind, and the gas heated rapidly and expanded so quickly that it lifted the balloon and its heavy equilibrator to an altitude of 3,000 feet before it could be checked. The rise was so rapid as to make the crew dizzy and affect their ear drums. Vaniman opened the valves to let out the hydrogen, meanwhile closely watching the statoscope for the first signs of descent. Despite the utmost precautions and the careful handling of the valves, the descent took place quite as suddenly as the ascent. As the balloon fell it gathered momentum and also lost buoyancy, due to the contraction of the gas bag in the increasing density of the lower strata of air. This contraction of the gas bag produced a constant downward accelerating force, greatly increasing the speed of the descent. However, the equilibrator served as a cushion to ease the fall. It entered the water at high speed and sank until the last can was submerged before the airship, relieved of its weight, could recover and rise again. This one experience was sufficient to show the value of the equilibrator.

Had there been no device of this nature provided, the airship must, inevitably, have been carried into the sea at the end of its downward plunge, striking the water at such a velocity as to have crushed out the lives of all on board. Had the airship started without an equilibrator, it would frequently have been necessary to throw over ballast to prevent such descents, and it would as frequently have been necessary to open the gas valves to prevent ascension to dangerously high altitudes. It was Vaniman's opinion that without the equilibrator the airship could not have kept afloat a single day. As it was, this single ascent cost fully one-seventeenth of the total supply of gas.

Monday, the third day out, the sailing was good; but the wind had veered around to such a direction as to drive the airship southward. It was then planned to head for the Azores Islands, and later in the day a still further shift of the wind made it necessary to head for Bermuda. The oscillatory motion continued under the action of the wind and it was necessary to lighten the balloon of still more gasoline.

When, early in the morning of Tuesday, the lights of the Trent were made out, it was decided that it would be foolish to continue the voyage farther. There remained but little gasoline in the main tank and much of the gas in the balloon had been wasted. There was every probability that the airship could keep afloat during the day, but the chances of staying in the air at night, when the reduced gas supply in the envelope would be condensed by the cold, were rather slim. Furthermore, there was the difficulty of launching the lifeboat with the heavy equilibrator trailing in its wake, and it seemed far more prudent to undertake to launch the boat while a vessel stood by ready to give assistance.

The problem of launching the boat was no small one. The airship was drifting at the rate of 15 knots, broadside to the wind, as may be seen by noting the angle which the white trail of the equilibrator makes with the shadow of the gas bag in the illustration, Fig. 31, taken from the deck of the Trent. This meant that the boat, which could not be swung athwart the car, would have to be launched sideways. The valves were opened until the boat dropped to within 4 feet of the water. All the materials that were saved from the airship were stowed in the bottom of the lifeboat to act as ballast. At a given signal, the automatic shackles which held the boat to the airship were released and the boat dropped into the sea. Despite the fact that it was traveling broadside at a rate of 15 knots, it did not ship a gallon of water. As soon as the balloon was released of this weight, it shot up into the air and the equilibrator was whipped out of the water, striking the boat and crushing the forward air compartment, fortunately above the water line. Before cutting loose from the airship, Vaniman tied a can to the gas valve of the balloon so that the latter would lose its gas, thus obviating any danger of its rising out of the sea and acting as a menace to the rigging of vessels at sea or buildings along the coast. When last seen, the balloon was settling, nose down, into the water.

Thus ended one of the most remarkable voyages ever undertaken, and certainly the most remarkable rescue at sea. The results accomplished were two records for dirigibles: One of duration which consisted of 71½ hours in the air, as against 36 hours, which was made by Zeppelin; and the other of distance, which was put at 1,008 miles by navigator Simon in his logbook, the previous distance record having been made by Zeppelin when he covered 800 miles without coming to earth. However, the object of the expedition was not to establish records. The underlying idea of Wellman and Vaniman has been to stimulate interest in dirigible balloons, to study their behavior under varying conditions, and to promote their development. It is a tribute to the skill of the engineer who designed the America that on its first voyage, without any preliminary trial, it broke all previous records, and, as far as the machinery is concerned, with the exception of the one defective engine, maintained

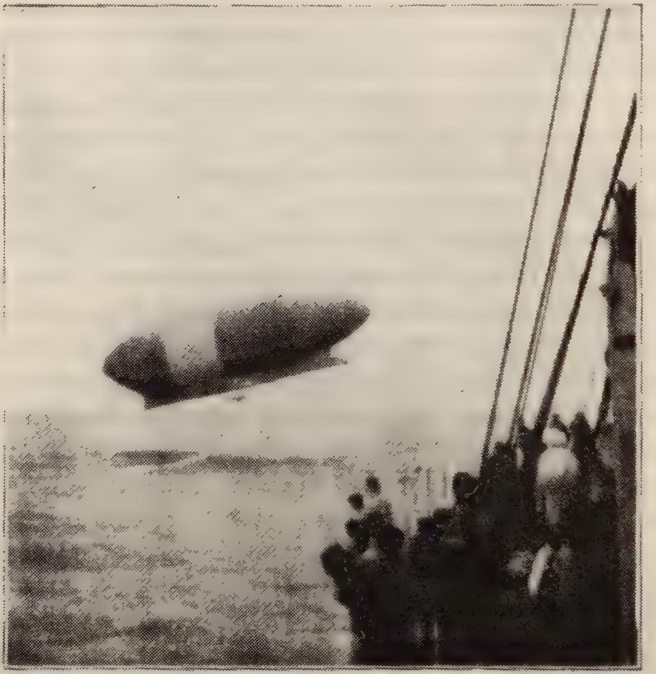


Fig. 31. View of the "America" Settling into the Sea Prior to the Release of the Lifeboat. Picture Taken from the Deck of the S. S. Trent

every part intact. Not a stay was broken and not a nut needed tightening during the voyage.

Brucker's Proposed Expedition. Wellman's contemporary, who intended to attempt a transatlantic voyage by dirigible in 1910, is Joseph Brucker, a German-American, whose project antedates Wellman's attempt. Owing to delays in getting ready, it was impossible to start before too late in the season—now it is proposed to carry out the expedition early in the Spring of 1912, but along somewhat different lines. Before describing Brucker's apparatus, a brief resumé of his comments on the reasons for Wellman's failure will be of interest. He says, quoting from *Umschau,* Berlin:

> I have repeatedly pointed out that in the present state of the art it will be impossible to cross the Atlantic in an airship north of the 35th parallel of latitude, because in that region one depression follows another, and particularly in the fall. Wellman was meteorologically ill-advised. At the time of his start, it was well known that a violent hurricane was raging in Cuba, and that such violent disturbances of the atmosphere in those latitudes are followed by extraordinary collateral phenomena in latitudes 35 to 40 degrees north. Wellman's chart of the journey confirms this.
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> It also seems that Wellman could not rely on his motors—one was disabled soon after he set out and the other was probably not powerful enough to enable the America to keep a more easterly course. The America seems to have traveled more like a free balloon, for which reason this performance should not be regarded as a record for dirigibles. Wellman would in all probability hardly maintain that he could follow a definite course. Another fatal error was the equilibrator, to which Engineer Vaniman pinned his faith. This was in itself a very cumbrous contrivance with its thirty gasoline tanks and turned out to be a source of danger.
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> Dr. Alt, of the Munich Meteorological Station, and I have made many experiments during the last few months with arrangements similar to Wellman's equilibrator. We have given the tanks most diverse forms, only to come to the conclusion that all such devices, when an airship is traveling over water, not only produce enormous resistance, but are highly dangerous to the airship itself. The America seems to have perished from appendicitis. A surgical operation, however, could not be performed, because the airship, if it had been relieved of this burden, would have risen to an enormous height and would have faced new dangers.
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> The expedition which I have organized is the result of scientific study. It is our intention to start from the Cape Verde Islands, about 2,350 miles from the Lesser Antilles. There are no counter winds in our course, no fogs, no storms, and, therefore, it should be possible to travel with the wind at a rate of about 7 meters (23 feet) per second or 15 miles an hour.

Brucker's selection of a route founded on taking advantage of a prevailing trade wind is not new. Edgar Allan Poe suggested the plan of sending a balloon drifting with the trade winds from Africa to America, in one of his realistic novels. In France, it had been seriously proposed even prior to this, and it was again taken up in the late nineties when Santos-Dumont was keeping interest in aeronautics alive in Europe by his experiments. Strange as it may appear, the first development of the dirigible caused these projects to be forgotten, for, with its aid, the primary idea was that the wind was to be overcome and not taken advantage of as in the spherical balloon. The chief remedy sought was increased speed, while Zeppelin's sole idea was to increase the radius of action in order that an airship might be capable of outlasting a storm.

To finance his project, Brucker incorporated the *Transatlantische Flug Expedition*, with a board of directors comprising some of the foremost scientific and commercial leaders of Germany. The stock has been subscribed by a number of individuals, though the Swiss chocolate manufacturing firm "Suchard" has guaranteed to meet most of the expense, hence, the name.

Type of Balloon. The balloon is of the type of the Parseval VI, but modified. It measures about 240 feet in length by 68 feet maximum diameter, which is at the first third of its total length, as in the Parseval. The bow is spheroid, or egg-shaped, while the stern is sharply pointed. The envelope has a capacity of 9,400 cubic meters (more than 330,000 cubic feet), the balloonet representing more than a third of this, or 3,500 cubic meters, which is equal to the total displacement of a typical French airship. This insures a rigid hull, even after an extensive loss of gas, enabling the ship to meet the most extreme conditions that are apt to rise in a long voyage. Efforts have been made to give not only a tremendous radius of action, but also the highest attainable degree of safety. Both of these requirements have been realized by building a ship of ample size designed for low speed. The weight thus saved is utilized to make a thoroughly strong structure and in equipping the vessel with safety appliances. In fact, the craft represents the very latest product of the German aerial dockyards.

The envelope is made of a special fabric consisting of three layers of cloth, two of rubber, and a light rubber coating on both surfaces. This, together with the large volume, and the ratio of four to one between length and diameter, resulting in a comparatively small surface per unit volume, should give excellent gas-retaining qualities. Even the Zeppelin VI, which was burned at Baden-Baden, retained its gas for many weeks at a time, although in daily service. In the Suchard, gas loss by diffusion will be negligible as compared with the amount escaping when the safety valves are opened under the tropical sun. This loss is to be minimized by a special patented device, which is perhaps the most important feature of the design of the entire apparatus.

Novel Features. Advantage has been taken of the fact that the route will be entirely over water. The plan is to scoop ballast from the ocean whenever needed by means of buckets on a steel cable. These buckets are of sheet steel of a shape to give the minimum resistance when filling. Each holds seven to eight gallons and has four holes in front to permit the water to enter, filling quickly and automatically by reason of the motion of the airship. Although they can be dropped into the water so that their action takes place immediately, the effect of the sun's rays is also very sudden, and dependence is not placed on this device alone. It is supplemented by a *movable weight,* the position of which regulates the inclination of the keel. With the aid of this arrangement, a certain amount of downward force can be called into play by aeroplane action through the forward movement of the vessel. It practically amounts to changing the angle of incidence as is done in an aeroplane with the elevating rudder.

But the most important feature is an original *device for cooling the envelope with running water.* Light canvas hose extends from the boat to the top of the balloon, where it encircles the gas valve and then extends back along the balloon in both directions. It is provided with a number of perforations along its sides, ending in a hard-rubber spray nozzle fore and aft. From a tank in the boat, water is pumped through the hose, flowing in a thin film all over the envelope. The 18-mile breeze caused by the travel of the airship will cause rapid evaporation, resulting in an intense cooling effect. When it is considered that the airship will have to undergo the extreme change from tropical day to night at least five to seven times, it will be evident that the conditions to be met are extremely more dangerous than those ordinarily encountered on land, where a single change from day to night in temperate zones causes most serious difficulties, so that it remains to be seen whether the results obtained with these safety devices will fulfill expectations.

Motive Power. Wellman's plan of utilizing a car and a lifeboat has been departed from by combining both in a large motor boat. This is 39 feet long by 12 feet beam and 7 feet in depth and is equipped with two 200-horse-power motors, which will not only drive the ship in the air, but the boat in the water, in case of abandonment. It is equipped with a fire- and explosion-proof gasoline tank, the efficacy of which was demonstrated in the accident to the Zeppelin VI, in which the tank remained intact though the ship was burned. The boat provides a navigating and living compartment, a complete machine shop for making repairs, a set of aeronautic and meteorologic instruments and a large store of provisions. It is suspended from the envelope in the same manner as the usual car, but between it and the envelope a light passageway is suspended, reached from the boat by a rope ladder. It gives direct access to the envelope and the valves and also provides additional "deck space." The whole equipment, however, is centered in the boat and nothing has to be transferred in an emergency as in the America.

It is hoped that the Suchard, with its speed of 18 miles an hour, plus the steady trade wind blowing 16 miles, will make 34 miles an hour, covering the distance in five days, if the machinery holds out. In case of breakdown, it will take longer, but the trade winds will insure steady progress, while there seem to be no risks that could be compared in the least with those that Wellman faced. A number of trial trips will be made before embarking on the actual enterprise with the trade wind, which allows of no return. In the light of Wellman's experience, Brucker's success would seem to depend upon his skill in handling the water-scooping and -spraying apparatus, *i. e.*, his ability in preventing the airship from rising unduly. If he succeeds in avoiding gas losses from this cause, he can hardly fail to reach the West Indies, even though the motors give out. But even a few minutes failure of these devices would suffice to send the ship to the clouds, blowing off large quantities of gas and spoiling all chances of a long voyage. The air balloonet is so large that it should compensate for considerable expansion or contraction of the gas.

Carrying Passengers by Airship. *Deutschland.* For a time, it seemed as if the year 1910 would go down in history as marking the actual inception of aerial transportation according to a regular schedule. The Deutschland (Zeppelin VII) was a true ship of the air and on a most elaborate scale. She was built for the *Deutsche Motorluftschiffahrt Gesellschaft* (German Aerial Transportation Company), incorporated to do an aerial passenger-carrying business. The airship was 490 feet long and had a capacity of 27,400 cubic yards. The budget of this aerial packet boat was as follows: The cost of the airship was to be $150,000, the gas bags to be half re-inflated every week, involving a monthly consumption of 390,000 cubic yards of hydrogen, representing an annual expenditure of $9,000; for a service of six months for fuel and lubricants $9,000 more was allowed; the crew of seven men were to receive $7,500, while $5,000 was allowed for anchorage rights; administration and unforeseen expenditures, $11,500, and a sinking fund of $75,000, bringing the total to $116,500, exclusive of the cost of the ship itself.

The passenger cabin of the Deutschland was built on an aluminum frame and lined with rosewood and mahogany, inlaid with mother-of-pearl, the walls consisting of mahogany veneer in several layers glued together, with a thickness of ¼ inch. The floor was also a mahogany veneer of the same thickness, carpeted, while the ceiling was only ⅛ inch thick, veneer being employed throughout to save weight. The entire cabin was 35 feet long by 7½ feet wide and weighed only 1,600 pounds. It was divided into five compartments, each containing four cane seats, of which 1 foot only was screwed to the floor, so that the chair could be swung in all directions. Beside these five 5-foot compartments, there was an entrance vestibule and a lavatory. The window openings were remarkably wide so that an unobstructed view could be obtained in every direction. No glass was used in them, however, although in the first compartment a sliding glass window had been provided for testing purposes.

Twenty-four passengers, among them an American woman, five Germans, and three Englishmen, booked passage at the established rate of $50 a trip, for the first voyage. All told, there were thirty-three persons on board the Deutschland on her first trip. She started from Friedrichshafen at 3 A. M., traveled up the valley of the Rhine as far as Cologne and reached Düsseldorf at 3 P. M., having covered 300 miles as the crow flies. Favored by the wind the speed is said to have reached 50 miles an hour at times, the distance from Mannheim to Düsseldorf (180 miles) having been covered in four hours; an express train taking six hours, on a rather winding track. The next day, the Deutschland made a round trip from Düsseldorf to Dortmund and back, going the 37 miles out in one hour, but taking three and one-half hours for the return. As a result, voyages at frequent intervals were announced.

On June 29, 1910, the Deutschland left Düsseldorf with seventeen passengers—all newspaper men—the voyage to last four hours, but the ship was still struggling against a strong head wind five and a half hours after the start at 8:30 A. M. Then the motors began to give trouble and the fuel threatened to run short. The wind had risen to a storm and, without the aid of its motors, the ship shot up to a height of 5,000 feet, then dropped as suddenly in the forest of Teutoburg, a huge tree trunk coming up through the floor of the cabin to the dismay of the passengers. However, it broke the fall and prevented a far worse disaster, supporting the great dirigible about 40 feet from the ground. The entire after part of the ship was wrecked, the governing planes (horizontal rudders) being broken and the gas bag being torn in many places. A company of infantry dismantled the wreck, dissecting the aluminum frame, piece by piece, packing the motors and parts of the car and rolling up the fabric of the envelope, so that, in a few hours, the airship was on its way back to Friedrichshafen on the railroad instead of in the air. Lieutenant Wagner, commanding the Deutschland, attributed the accident to a combination of adverse circumstances and not to any fault of the system. The chief cause was the sudden downward whirlwind, but if the fuel had held out, the gale might have been weathered. As it was, she was at the mercy of the wind. In rising so high, a great deal of gas was lost and the wetting of the envelope in the rain caused a dangerous loss of buoyancy.

Zeppelin VI. A little less than two months later, the Zeppelin VI was also destroyed. On September 14, owing to a breakdown of one of the motors, the envelope caught fire while the crew was cleaning the machinery with gasoline from an open tank. The hydrogen in the seventeen compartments instantly ignited and the ship was completely consumed in a short time. During the fortnight preceding the fire, the Zeppelin VI had covered 2,000 miles and had carried more than 300 passengers. She was the speediest Zeppelin ever built, being credited with a speed of 38 miles an hour. On August 28, for the third time in eight days, she carried thirty passengers from Strasburg to Baden-Baden and back in three hours.

Miscellaneous Exploits. Earlier in the year, the Zeppelin II —one of the German military fleet—was also destroyed by a storm. While journeying from Hamburg to Cologne, it was necessary to anchor in an open field. On April 25, 1910, after the vessel had just received a new charge of gas, two companies of soldiers were unable to hold it down in a high wind and it was blown away. It immediately rose to a height of 700 feet and sailed away with the wind; twenty minutes later it was blown to the ground in the Lahn Valley, the bow caught in the telegraph wires and then the wind took the huge gas bag broadside and hurled it against the side of the hill at Webersburg, completely demolishing it. This accident affords a striking illustration of the chief shortcoming of the dirigible—its utter helplessness when exposed to the wind, a cause that led to the loss of La Patrie three years before, when the company of soldiers detailed for that service were unable to hold the ship and it simply blew away, never being heard of again. To be of practical use, the dirigible must be large, but its very size is its greatest element of weakness, as the cost of erecting numerous sheds to accommodate it would be prohibitive, and it can not safely anchor in the open.

In addition to the events chronicled, there were a number of successful cross-channel flights, the most striking being the round trip of the Clement-Bayard II between London and Paris, which merely afforded an excellent example of what may be done under favorable circumstances. In fact, the English Channel was crossed not less than three times in a month by airship, one of the trips being made in an English dirigible, by E. T. Willows, who had a short time prior flown from Cardiff to London. He started for Paris from London, but was compelled to descend 50 miles inland from Calais.

Despite the number of huge dirigibles that were wrecked in Germany during 1910, as well as those that came to grief in England in the following year, a great impetus has been given their building and operation for passenger service in the former country, and numerous inventors are devoting attention to the perfecting of various devices to aid in their navigation. The pilot of a huge dirigible has many things to watch, but none that requires closer attention than that of the vertical travel of the ship, to keep track of which the barographs, anemometers, and anemoscopes must be consulted continually, often to the neglect of other duties, which gives rise to dangerous situations.

Kodophone. The kodophone is an instrument specially devised for the purpose of relieving the pilot of a dirigible of the nerve-racking strain of watching a number of fine instruments to detect whether his ship is rising or falling. As its name indicates, it works on an audible rather than a visual principle. The device consists of a wind wheel located horizontally in a cylindrical metal casing and adapted to revolve easily on a vertical shaft. The metal cylinder is in turn protected by a heavy wicker basket. The wind wheel is accordingly so placed that only a vertical current of air will actuate it. A slight amount of vertical play is allowed the wheel on its vertical shaft, so that if the wind is coming from below, the wheel will rise slightly under the pressure of the wind turning it and will operate a bell above it. This would indicate that the airship was falling. With the wind coming from above, the process would be reversed and another bell of a different tone sounded. Not alone the fact that the airship is either ascending or descending, but likewise the speed and the entire period during which one or the other takes place, are directly communicated to the pilot by the bells. When both are silent, he knows with absolute certainty that the airship is traveling on a perfectly horizontal keel. This is of the greatest importance at night, when the necessarily limited amount of light on the instruments makes consulting them more than usually troublesome. It also has a further advantage in that the instruments merely show that the ship has fallen or has risen and does not reveal whether one or the other is continuing, except by close observation. To avoid disturbance due to horizontal currents being deviated into the basket by the propeller or similar means, the metal cylinder is covered at the top and bottom by fine wire gauze. It will be at once apparent that the pilot, being thus continuously informed by the bell signal, will be able without loss of time to take prompt measures for correcting any unfavorable action, saving both gas and ballast and increasing the range of the ship.

Another instrument that the aeronaut finds need of now that greater altitudes and night flights have become more common, is one that will enable him to determine his position readily. Under the circumstances, indirect methods must naturally be reverted to and several such methods have been tried in the past few years. Magnetic measurements have been employed for this purpose and successful methods of informing an aeronaut of his position by wireless telegraphy have been devised. Finally, astronomical methods have been proposed, in which the tedious reduction of the observations is effected by special apparatus. This method, of course, can be employed only at night in clear weather.

Special Aeronautical Compass. The ordinary compass is not of great value to the aeronaut or the aviator, as the direction of travel must be figured out from the indication of the compass needle, aided by the chart, all of which requires concentration that it is difficult to give when attention is required by so many other things. To overcome this, a special type of compass has been invented by an American, A. G. Marquis. It consists of a needle mounted in the usual manner, while surrounding it in the same horizontal plane is a card having the points of the compass marked on it. This chart is reversed, however, as to north and south, and the needle is so arranged that it points to the south also. The result is that the reflection in a mirror placed at an angle of 45 degrees above the chart is correct, the north point appearing at the top and the south at the bottom of the mirror. Instead of the chart moving round and the needle remaining stationary as in the ordinary compass, the needle itself apparently swings with each alteration in the course, and continuously indicates the direction in which the airship or aeroplane is traveling. The apparent movement of the pointer is the result of an optical illusion, for the needle actually remains stationary and the chart turns in the usual way. With a liquid of comparatively heavy specific gravity to deaden the vibrations of the needle, this has been found to be by far the most practical and ingenious of the many special types of compasses that have been advocated for aeronautical use. One of the best methods of overcoming vibration has been found to be the use of oil for floating the needle and a bed of springy horsehair for holding the compass case. The employment of a compass with a south-pointing needle dates back to 2600 B. C. in China, where it was used for land "navigation."

EXAMINATION PAPER.

DIRIGIBLE BALLOONS

Read Carefully: Place your name and full address at the head of the paper. Any cheap, light paper like the sample previously sent you may be used. Do not crowd your work, but arrange it neatly and legibly. *Do not copy the answers from the Instruction Paper; use your own words, so that we may be sure you understand the subject.*

---

1. What essential features of design did Meusnier's first dirigible incorporate?

2. Describe the difference between the rigid, semi-rigid, and flexible types of dirigibles.

3. Take any modern dirigible of the flexible type as an example and point out the manner in which it embodies the principles laid down by Meusnier.

4. Why can not the dirigible be driven as fast as the aeroplane? Why does it require so much more power to drive a dirigible than an aeroplane?

5. State the laws governing the increase of resistance with speed, the increase of power necessary for a given increase of speed, and the ratio in which volume and area of the gas bag increase with increased dimensions.

6. What provides the lifting power of the dirigible and how is this lifting power utilized? Why should this lifting power be so much less at night than in the daytime? What is net lifting power?

7. What are air-balloonets? How are they used, and what for?

8. What is the most efficient form of envelope for the dirigible and why?

9. Why can not the ordinary spherical balloon be propelled as a dirigible?

10. Is the form of the stern as important as the bow?

11. Why is it not practical to build small dirigible balloons? Are there any limitations as to size in the other direction and what are they?

12. What is longitudinal stability and how is it obtained?

13. Explain the necessity of having the center of thrust and the center of gravity as far apart as possible in the flexible type.

14. How is stability of direction obtained? What are stabilizing planes?

15. Why must a form of suspension for the car that can not be accidentally displaced with relation to the balloon, be provided?

16. Define *static* and *dynamic equilibrium* as applied to the dirigible.

17. Why would it not be practical to carry along an extra supply of hydrogen gas under high pressure to replace loss through leakage, or compulsory opening of the gas valve to prevent rising too high? How has it been recently proposed to avoid use of ballast and valve regulation?

18. Theoretically, where should the propulsive effort be applied to a dirigible? What factors affect the placing of the propeller, and what has been proven to be the most practical solution of the problem?

19. What may be said to represent the usual practice in the placing and in the number of propellers employed? How did this part of the equipment of the America differ and for what reason?

20. What is the radius of action of a dirigible? What factors affect it, and how?

21. What is the difference between "pounds per horsepower" and "pounds per horsepower hour" as applied to the motor of a dirigible? Which is more important?

22. Why should the power plant of a dirigible be in the form of two independent motors where a great radius of action is desirable?

23. Assume a dirigible having a maximum speed of 30 miles per hour. Its lifting power enables it to carry sufficient fuel for ten hours running at full speed. What would the radius of action of such an airship be (a) in a perfect calm; (b) with a head-wind of 15 miles per hour, which only blew for five hours after starting and then dropped to a perfect calm?

24. Explain the theory of the "equilibrator" used on the America. How did it actually work in practice, and why?

After completing the work, add and sign the following statement:
I hereby certify that the above work is entirely my own.
(Signed)

SHOREY

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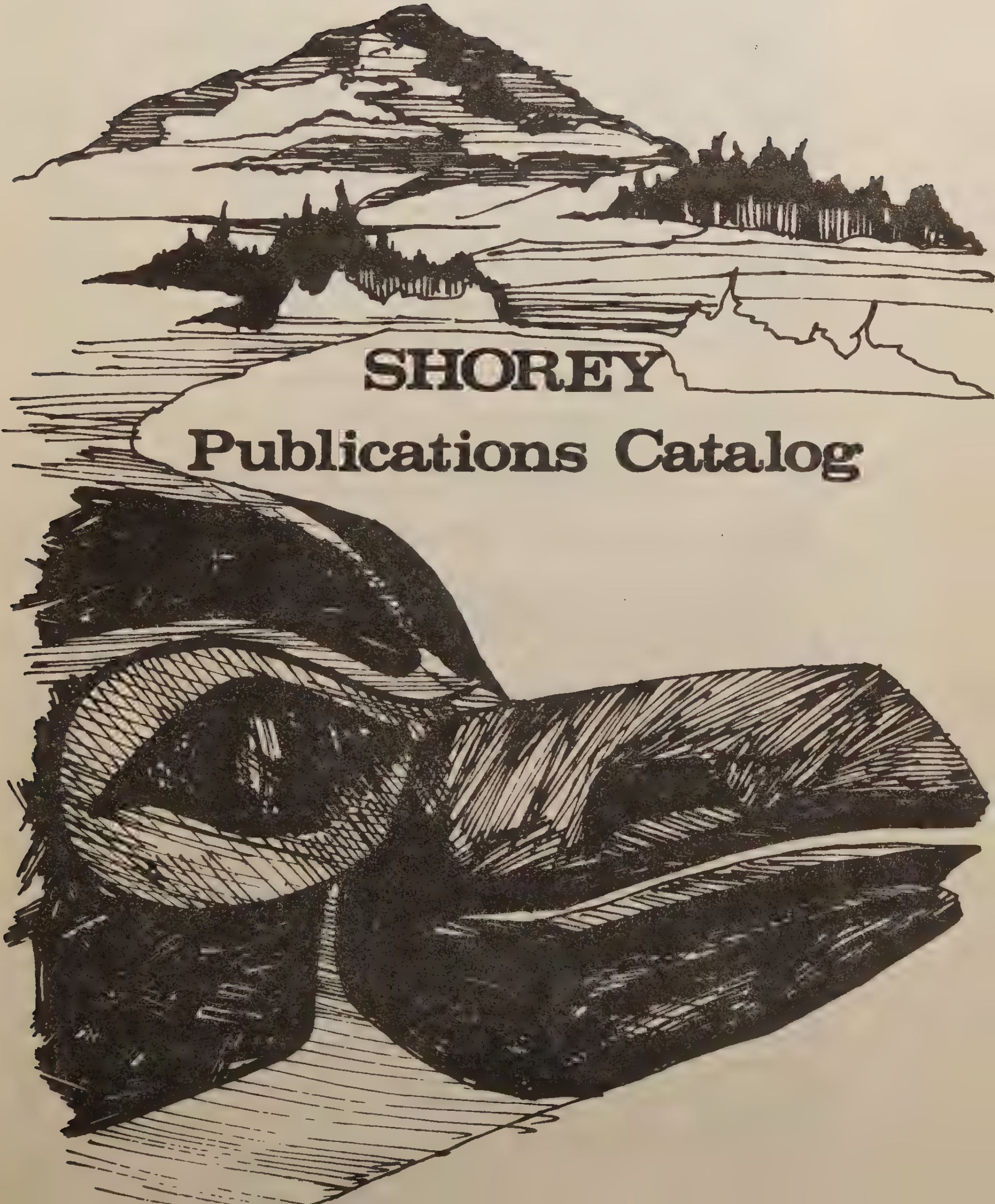

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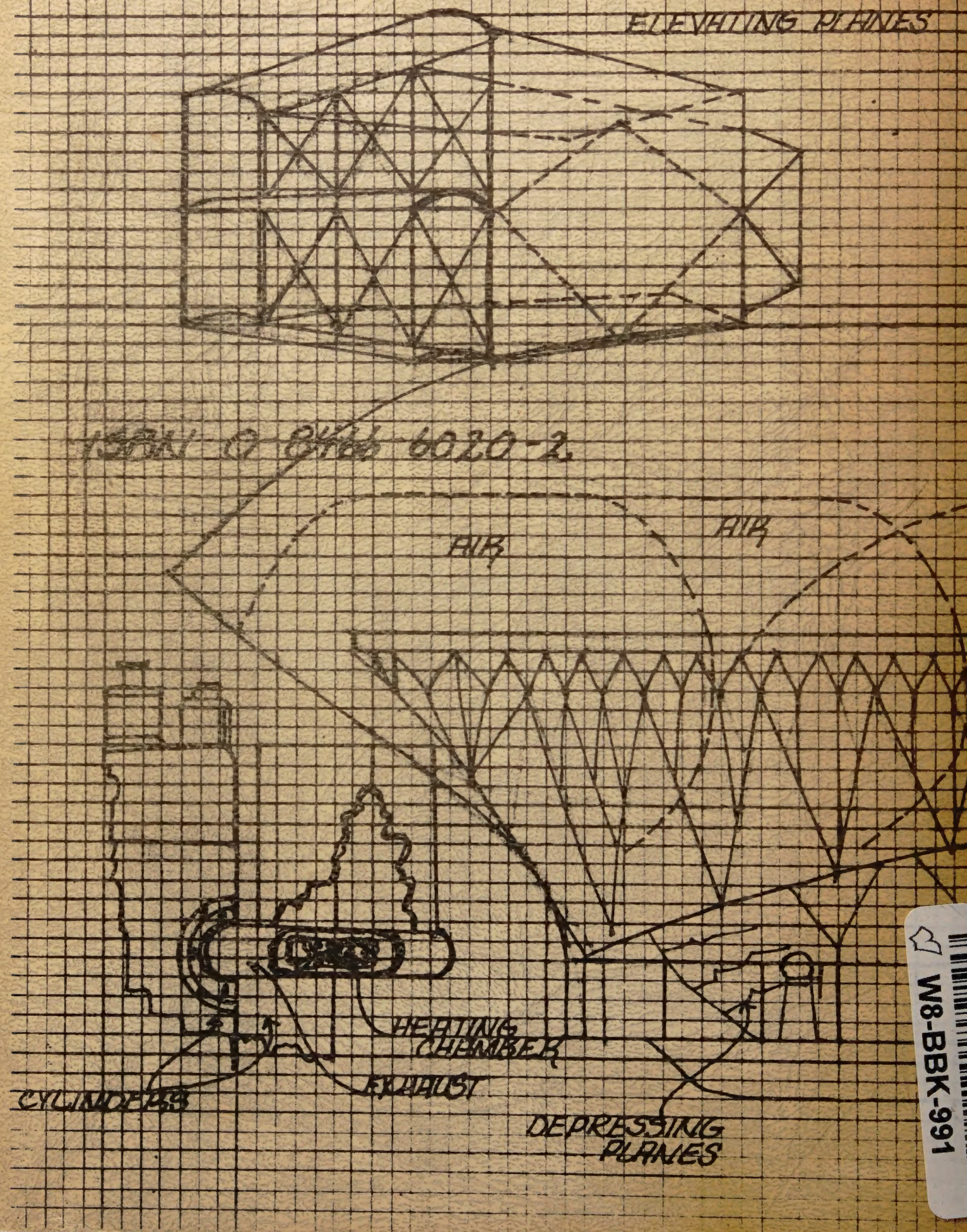

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